



THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No. : 10/699,212 Confirmation No.: 2780  
Applicant : David R. Hennings  
Filing Date : October 30, 2003  
Title : Endovenous Closure of Varicose Veins with Mid-Infrared Laser  
Group Art Unit : 3735  
Examiner : David M. Shay  
Docket No. : 15487.4002  
Customer No. : 34313

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**SUPPLEMENTAL APPEAL BRIEF AND REQUEST FOR ORAL HEARING**

Sir:

***Real Party in Interest***

CoolTouch, Inc., a wholly-owned subsidiary of New Star Laser Company, is the real party in interest.

***Related Appeals and Interferences***

There are no known related appeals or interferences.

***Status of Claims***

Claims 1-17 and 19-23 and 25-46 are pending in this application. These claims have all been rejected and are the claims on appeal. Claims 18 and 24 have been cancelled.

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Lynne Fulmer

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### ***Status of Amendments***

All amendments which Applicant has filed have been entered.

### ***Summary of Claimed Subject Matter***

There are four independent claims, which are claims 1, 14, 25 and 35, in the present application. Claims 1, 25 and 35 are method claims and claim 14 is a system claim, all of which are directed to the treatment varicose veins.

Claim 1 reads as follows:

“1. An endovenous method of treating a varicose vein comprising the step of using a laser having a wavelength between about 1.2 and about 1.8 um to heat and shrink collagen in a varicosed vein to destroy the functionality of the varicose vein.”

This method is illustrated schematically in Figures 3A-6 and in more detail in Figures 7 and 8. As described in paragraphs 47-50 of the application, the method comprises using a laser fiber 306 (which has been deployed through dilator 300) into vein 202. This is described in paragraph 47 of the specification as follows:

“FIG. 3B is a representative view showing the use of the introducer or dilator 300 with the laser fiber 306 passing through the lumen 302 of the dilator 300 and into the GSV (greater saphenous vein) 202 ...”

The use of a laser having a wavelength between about 1.2 and about 1.8 um is described in paragraph 52 as follows:

“The 1.2 to 1.8 um laser wavelengths are ideally suited to penetrate the small amount of remaining blood in the vessel 200 but also is much more strongly absorbed in the vessel wall 704 by collagen. Most of the energy is concentrated in the wall 704 for heating and

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shrinkage and is not transmitted through to surrounding tissue 702.”

Claim 14 reads as follows:

“14. A system for endovenous treatment of varicose veins comprising the following:  
A laser having a wavelength between about 1.2 and about 1.8  $\mu\text{m}$ ;  
and  
A fiber optic laser delivery device having a proximal end and a distal end, for delivery of laser energy from the distal end of the fiber optic laser delivery device to the inside wall of a varicose vein wherein the functionality of the varicose vein is destroyed and collagen in the varicosed vessel wall can be heated and shrunk.”

The system of claim 14 is illustrated in Figure 1 and in more detail in Figure 3B. In Figure 1, laser console 102 is illustrated and it is disclosed in paragraph 54 that laser 102 can be used to provide laser wavelengths in the 1.2 to 1.8  $\mu\text{m}$  region. In Figure 3B, the fiber optic laser device 306 is illustrated and described in paragraph 47 as follows:

“FIG. 3B is a representative view showing the use of the introducer or dilator 300 with the laser fiber 306 passing through the lumen 302 of the dilator 300 and into the GSV (greater saphenous vein) 202 ...”

The function of this system to deliver energy to heat and shrink the collagen in the vessel wall is described as follows in paragraph 52:

“The 1.2 to 1.8  $\mu\text{m}$  laser wavelengths are ideally suited to penetrate the small amount of remaining blood in the vessel 200 but also is much more strongly absorbed in the vessel wall 704 by collagen. Most of the energy is concentrated in the wall 704 for heating and shrinkage and is not transmitted through to surrounding tissue 702.”

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Claim 25 reads as follows:

“25. An endovenous method of treating varicose veins with laser energy to heat and shrink collagen in the vein and to destroy the functionality of the varicosed vein, the method comprising the following steps:  
inserting a laser delivery device into the varicose vein;  
delivery laser energy having a wavelength between about 1.2 and about 1.8  $\mu\text{m}$  to the varicose vein; and  
retracting the laser delivery device through the varicose vein, thereby heating and shrinking the collagen in the vein and destroying the functionality of the varicose vein.”

The first two steps of claim 25 are illustrated and described as set forth above with regard to claim 1. The step of retracting the laser delivery device is described in paragraph 51 as follows:

“The catheter 32 is connected to a motorized pullback device 104 either inside or outside of the sterile field 108 of the patient. The procedure begins by starting the pullback for about 2 or 3 mm and then turning the laser 102 on at about 5 watts of power. The pullback device is illustrated schematically in Figure 1 as element 104. ”

Claim 35 reads as follows:

“35. A method of treating varicose veins, comprising providing a beam of light comprising a wavelength in the range of about 1200 nm to about 1800 nm; and delivering endovascularly the beam of light to target a chromophore comprising water in the wall of a targeted varicose vein to treat the vein.”

This method is illustrated in Figure 3B and is described in paragraph 47 as follows:

“FIG. 3B is a representative view showing the use of the introducer or dilator 300 with the laser fiber 306 passing through the lumen 302 of the dilator 300 and into the GSV (greater saphenous vein) 202...”



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According to the preferred embodiment of the method and apparatus of the present invention.  
the method is further described in paragraph 52 which states:

“The 1.2 to 1.8 um laser wavelengths are ideally suited to penetrate the small amount of remaining blood in the vessel 200 but also is much more strongly absorbed in the vessel wall 704 by collagen. Most of the energy is concentrated in the wall 704 for heating and shrinkage and is not transmitted through to surrounding tissue 702.”

Water absorption of laser energy in the region between about 1200 nm to about 1800 nm is disclosed in paragraph 65 and is illustrated in Figure 10. In paragraph 65, it is stated:

“It will further be observed that the region between about 1200 nm to about 1800 nm shows low hemoglobin and higher water absorption, which is a key to the present invention.”

With regard to the dependent claims, the fiber optic delivery device of claims 2, 14 and 38 is illustrated as element 306 in Figure 3B and is described in paragraph 47.

The procedure of claim 5 in which the pullback device begins retraction of the fiber optic device prior to initiating delivery of the laser energy is disclosed in paragraph 51.

The use of a diffusing tip on the optical fiber recited in claims 8, 19 and 39 is illustrated in Figures 9A, 9B and 9C and is described in paragraphs 62, 63 and 64 as well as in paragraphs 59-61.

The non-contact thermal sensor of claims 9 and 21 is described in paragraphs 55 and 56. Providing the fiber optic laser delivery device with a thermal sensing element as recited in claim 12 is described in paragraph 55.

The procedure of modulating the laser power based on the sensed temperature as recited in claims 13 and 23 is described in paragraph 55.

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The use of a laser having a wavelength of about 1.32 um as recited in claims 26-28 and 37 is disclosed in paragraph 53 and paragraph 79.

The use of a Nd:YAG laser as recited in claims 29-31 is disclosed in paragraphs 53 and 54.

The preferential heating of water in the wall of the vein as recited in claims 33-35 is disclosed in paragraphs 65 and 79. It is also disclosed in paragraph 21.

The use of laser power between about 1 to about 20 watts as recited in claim 45 and the use of laser power of about 5 watts as recited in claim 46 is described in paragraph 51.

***Grounds of Rejection To Be Reviewed on Appeal***

Claims 1, 2, 6, 7, 25, 35-38, 40, 41 and 44-46 have been rejected under 35 U.S.C. § 103(a) as unpatentable over Goldman Patent No. 6,258,084 in combination with Sinofsky Patent No. 5,196,004 and Dew Patent No. 4,854,320. Claims 3-5, 42 and 43 have been rejected under 35 U.S.C. § 103(a) as being unpatentable over Goldman in combination with Sinofsky, Dew and Roth Patent No. 5,207,672. Claims 8 and 39 have been rejected under 35 U.S.C. § 103(a) as being unpatentable over Goldman in combination with Sinofsky, Dew and Conn PCT Application No. WO 92/17243. Claims 9-13 have been rejected under 35 U.S.C. § 103(a) as being unpatentable over Goldman, in combination with Sinofsky, Dew and Makower PCT Application No. WO 93/15664. Claims 14-17 and 20-23 have been rejected under 35 U.S.C. § 103(a) as being unpatentable over Makower, in combination with Roth and Dew. Claim 19 has been rejected as unpatentable over Makower, in combination with Dew and Roth.

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### ***Declarations***

Applicant has submitted declarations under 37 CFR 1.132 together with exhibits. These declarations and exhibits are attached hereto as an evidence appendix in conformance with 37 CFR 41.37(c)(1)(ix).

### ***Argument***

#### Preface

The rejections of record should be reversed because:

- (a) Goldman, the only reference directed to treatment of varicose veins is primarily directed to RF treatment and is non-enabling in its mention of lasers.
- (b) The remaining references have nothing to do with the treatment of varicose veins.
- (c) The Examiner has refused to consider the evidence of unobviousness submitted by applicant.

The issues developed during the prosecution of this application could be entitled “two different worlds”.

One is the real world of treatment of varicose veins. The other is a patchwork world created by the Examiner from unrelated pieces of prior art. The real world evolution of the treatment of varicose veins began, for relevant purposes, with Goldman Patent No. 6,258,084 which disclosed, virtually entirely, the use of RF energy to a varicose vein to **shrink** it. In this Goldman patent, one sentence fragment makes only a passing and nonenabling reference to the use of lasers at column 7, lines 53-59 as follows:

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“Furthermore, although the invention will be described as using RF energy from the electrode, it is to be understood that other forms of energy such as microwaves, ultrasound, direct current, circulating heated fluid, radiant light, and **lasers** can be used, and that the thermal energy generated from a resistive coil or curie point element may be used as well.” (emphasis added)

Goldman contains no other reference to lasers and says absolutely nothing which would enable the use of a laser and absolutely nothing about either the wave length of the laser energy to be used or the chromophore to be targeted by the laser energy.

In this real world, the next development is reflected by Navarro Patent No. 6,398,777 which, rather conspicuously, has **not** been relied upon by the Examiner. Navarro discloses the use of laser energy having a wavelength from about 532 nanometers to about 1064 nanometers, i.e., laser energy which will be preferentially absorbed by the blood in the vein and not by the water in the vein wall. The mechanism of heating in such a procedure is the formation of steam bubbles in the blood which heat the inner wall of the blood vessel, which causes **thrombotic occlusion, not shrinkage** as is the case with Goldman’s RF heating.

The next development was the invention to which the present application is directed which involves the use of laser energy having a wavelength in the range of about 1200 nanometers to about 1800 nanometers which is preferentially absorbed by the water in the wall of the varicose vein.

As will be seen from the following discussion, Applicant’s choice of wave lengths which localizes heating in the **wall** of the vessel, **rather** than **heating the blood** to form steam bubbles **inside** the blood vessel, was directly contrary to the prevailing view of those skilled in the art that an increase in wave length beyond 1,064 nm was undesirable because of danger to the tissue surrounding the vessel wall, including the danger of skin burns.

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Instead of following this prevailing view, Applicant was a trail-breaker and found that, by switching chromophores from blood to water, the localized heating of the water in the vessel wall decreased rather than increased the danger of damage to the surrounding tissue.

Subsequent to Applicant, at least one other worker has followed in his footsteps. See Pathankar, 2005/0015123, filed June 30, 2004, based on a provisional application filed on June 30, 2003, which discloses the use of wave lengths of 1160 nm to 2600 nm in the treatment of varicose veins. Pathankar confirms, in paragraphs 53 and 54, that using energy having the wave lengths claimed by Applicant minimizes collateral damage to “tissue surrounding the target blood vessel.”

The other world is that created by the Examiner. During the prosecution of this application, the Examiner elected to dismiss foregoing history to such a substantial extent that there is no rejection of any claim based on Navarro Patent No. 6,398,777 which is the only patent of record which is directed to laser treatment of varicose veins (apart from the non-enabling sentence fragment referring to lasers in Goldman), even though Navarro is plainly the closest reference of record. However, to repeat, the Navarro disclosure is limited to lasers which deliver energy having wavelengths from about 532 nanometers to about 1064 nanometers which is well below the range of about 1200 to 1800 nanometers recited in the claims of the present application and targets a different chromophore, blood, than that of Applicant, water in the vessel wall.

Instead, the Examiner has attempted to combine Goldman, which is directed to the treatment of varicose veins, but enables only RF treatment, with one or more of the following references, which are directed to unrelated uses:

Sinofsky – a patent directed to the removal of atherosclerotic plaque using laser energy having a wavelength in the range of 1400 to 2200 nanometers with a preferred range of 1900-2100

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nanometers, i.e., to a treatment for increasing blood flow through a blood vessel rather than shutting down the functionality of the blood vessel as claimed in the present application.

Dew – a patent directed to the use of “laser energy either to heal or reconstruct tissue, rather than to destroy tissue.” (column 3 lines, 31-33), i.e., the diametric opposite of destroying the functionality of a blood vessel as claimed in the present application. Dew discloses use of laser energy having a wavelength of 1320 nanometers by tuning an Nd:YAG laser, which has a dominant wavelength of 1060 nanometers.

Roth – this patent is directed to treatment of benign prostate hypoplasia (BPH) using an Nd:YAG laser having a “standard wavelength” of 1064 nanometers (column 12, line 33). The emphasis in this patent is on a pull-back device to control the delivery of laser energy.

Makower – this published PCT application is also directed to the treatment of benign prostate hypoplasia and also discloses the use of an Nd:YAG laser at page 8, line 24, but has no disclosure regarding wavelength. The emphasis in this reference is on a locking means to hold the energy delivery cannula in place when performing a treatment.

Conn – This published PCT application is directed to a diffuser tip on a laser.

Thus, when all is added up, the collection of references relied upon by the Examiner amounts to attempting to combine Goldman which is virtually entirely directed to radiofrequency heating of varicose veins and which has only a passing, non-enabling, mention of the possible use of lasers (column 7, line 57), with references directed to the entirely different treatments of atherosclerotic plaque, tissue healing and benign prostate hypoplasia, all the while ignoring the Navarro patent which is directed to the laser treatment of varicose veins.

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All of the foregoing more than suffice to make it clear that the claim rejections of record involve an attempt to combine the uncombinable and that the references have been stitched together in an effort to reconstruct the claimed invention without regard to context and without regard to the antithetical nature of the references. But there is more, a lot more.

### The Scientific Literature

The Board's attention is called to Exhibits A, B and C to the Geriak Declaration filed November 22, 2005 which are, respectively:

Exhibit A – “Endovenous Laser Treatment of Saphenous Vein Reflux: Long-Term Results,” by Robert J. Min, M.D., et al., *Journal of Vascular and Interventional Radiology*, August 2003.

Exhibit B – “Thermal Damage of the Inner Vein Wall During Endovenous Laser Treatment: Key Role of Absorption by Intravascular Blood,” by T. M. Proebstle, M.D., et al., *Dermatologic Surgery*, July 2, 2002.

Exhibit C – “Endovenous Treatment of the Greater Saphenous Vein with a 940-nm Diode Laser: Thrombotic Occlusion After Endoluminal Thermal Damage by Laser-Generated Steam Bubbles,” by T. M. Proebstle, M.D., et al., *Journal of Vascular Surgery*, April 2002.

These papers appeared in the scientific literature in the same time frame as the filing of Applicant's provisional application on October 31, 2002 and the filing of the present application on October 30, 2003. Thus, they reflect the state of scientific knowledge in that time frame. Among other things, the mechanism of activity of the various types of vascular vein treatments are discussed.

With regard to the RF heating of Goldman, the Min article, Geriak Exhibit A, states, in the paragraph bridging pages 994 and 995, the following:

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“RF current damages tissue by resistive heating of structures in direct contact with the electrodes. Deeper tissue planes are heated by conduction into normothermic tissue. Because the potential for heating of adjacent perivenous tissue is high, safe treatment with RF depends on proper delivery of adequate tumescent anesthesia.”

The Proebstle paper, Geriak Exhibit B, further explains an important difference between endovenous laser treatment at 810 nm to 980 nm which the article labels EVLT and RF treatment which the article labels VNUS treatment as follows at page 596, first paragraph:

“It has been shown that EVLT, unlike VNUS, does **not** lead to occlusion of the vein by **significant shrinkage** of the vessel wall, but **instead** causes a **thrombotic occlusion** of the laser-treated vein.” (emphasis added)

Thus, the prior art laser treatments of varicose veins relied on a different mechanism than the RF treatment of Goldman and this fact was apparently unknown to Goldman. This Proebstle paper focuses primarily on laser treatment at a wavelength of 940 nanometers, but also discusses treatment at 810 and 980 nanometers. It explains that when laser energy at these wavelengths is used, the heating mechanism is the formation of steam bubbles in the blood which causes the thrombotic occlusion rather than shrinkage of the vein as when RF heating is employed. At page 599, at the top of the left-hand column, this article goes on to say:

“EVLT almost completely lacks the shrinkage effect of the vessels caused by prolonged exposure to moderate heat (85° C) in radiofrequency occlusion. Instead, EVLT causes perforation of the vein wall at the site of direct laser impact, as a morphologic correlate for the consecutively observed perivenular ecchymoses.”



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Furthermore, this Proebstle paper makes it plain that the choice of laser energy having wavelengths of 810, 940 and 980 nanometers had a reason and that reason is explained at page 599 in the right column in the right column in which Proebstle states:

“Evidence that blood plays not only a key role in absorption of 940 nm laser energy but also an absorption of 810 nm and 980 nm laser energy was provided by in vitro examination of steam bubble generation. While neither normal saline nor plasma were able to absorb laser energy substantially enough to generate steam bubbles, all three tested lasers produced comparable steam bubbles when exposed to hemolytic blood. Such steam bubbles, in all three laser systems, indicate that blood temperature passes the point of boiling at the site of the laser tip, thus transferring heat energy homogeneously to the inner vessel wall.”

This Proebstle paper cites to a Goldman article in footnote 2 and to a Navarro article in footnote 3 and these articles parallel the disclosures in the Goldman and Navarro patents.

Returning to the Min paper, Geriak Exhibit A, Min makes the point, at page 994, in the second paragraph under the heading “Discussion”, that the RF energy treatment of Goldman had complications which “included transient paresthesias, skin burns, deep venous thrombosis and on pulmonary embolus.”

Min further notes, on page 995, that treatment with laser energy at a wavelength of 1,064 nm resulted in “significant complications” which included “paresthesias and skin burns.” In addition, all patients in a study using 1,064 nm laser energy underwent spinal or general anesthesia rather than strictly local tumescent anesthesia. Still further, at the top of the right-hand column on page 995, Min characterizes treatment with 1,064 nm laser energy as resulting in “deeper penetration of laser energy and less-homogeneous heating” as compared with treatment at 810 nm.

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Thus, Min plainly **teaches away** from using the higher wavelength of 1,064 nm and indicates 810 nm to be preferable. The claims of the present application, which are directed to the use of laser energy between about 1200 and 1800 nm, plainly take a direction contrary to that indicated as desirable by Min. Furthermore, the use of Applicant's energy wave lengths does not make use of the steam bubble mechanism of energy with wave lengths of 810 nm to 1,064 nm, but rather causes direct heating of the vessel wall which results in shrinkage and disappearance of the vein as described in paragraph 77 of the present application.

Min, like both Proebstle papers, cites to Goldman and Navarro in footnotes 3 and 12. It is completely understandable that the scientific literature makes no mention of the Dew, Sinofsky, Makower, Roth, or Conn references relied upon by the Examiner. Those references have nothing to do with the technology of varicose vein treatment.

#### The Real World of Laser Treatment of Varicose Veins

Attached as Exhibit A-E to the Hennings declaration are product information publications by five providers of laser devices for treating varicose veins.

Exhibit A is a Dornier MedTech publication recommending laser energy having a wavelength of 940 nm which is represented to be superior to both 810 nm and 1,064 nm.

Exhibit B is a biolitec publication which espouses the use of 980 nm laser energy rather than 810 nm or 940 nm.

Exhibit C is an AngioDynamics publication for its 980 nm laser device for varicose vein treatment.

Exhibit D is a publication from Vascular Solutions which describes its varicose vein laser treatment which delivers laser energy at wavelengths of 810 nm, 940 nm and 980 nm.

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Exhibit E is a Diomed publication which describes its 810 nm device for varicose vein treatment.

Thus, those, other than Applicant, who have entered the market with laser devices for treating varicose veins subsequent to the issuance of Navarro Patent No. 6,398,777 on June 4, 2002, have all used lasers operating at one or more of the wavelengths 810 nm, 940 nm and 980 nm. All of these patents rely on laser wavelengths which will be absorbed by blood and cause the formation of steam bubbles in the blood to indirectly heat the inner wall of the blood vessel. In marked contrast, Applicant uses wavelengths of about 1200 nm to about 1800 nm, well beyond the upper limit of 1,604 nm contemplated by Navarro and the scientific literature, and does not use the steam bubble mechanism.

In the final rejection dated February 12, 2007, the Examiner has the following to say about the scientific literature and the activity of those in the real world of varicose vein treatment:

“Applicant then posits that in the real world those attempting to use lasers ‘to accomplish the purpose of Goldman’ deliberately chose not to use Applicant’s wavelengths. The Examiner must respectfully disagree. Firstly, it is noted that the three articles submitted by Applicants do not constitute a statistically significant sample of all the publications dealing with laser treatment of varicose veins and as such, cannot be the basis for a claim such as made by Applicant. Secondly, the ‘purpose of Goldman’ is to heat the vessel wall (see, for example column 9, line 13). The purposes of the articles submitted by Applicant is (sic) to heat the blood in the vessel. And, as clearly taught by Dew et al. and set forth above, this is achieved by employing wavelengths that are absorbed by the tissue that is desired to be heated.”

The Examiner’s summary refusal to consider the evidence submitted by Applicant is contrary to law. As held in In re Sullivan, \_\_\_\_ F.3d \_\_\_\_ (Fed. Cir. 2007), 2007 U.S. App. Lexis 20600,

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evidence submitted by a patent Applicant must be given meaningful consideration. The Examiner's statement that the articles do not constitute a "statistically significant sample" of "all the publications dealing with laser treatment of varicose veins" is both seriously misguided and unsupported by identification of any other such publications. No scientist living or dead would refuse to consider articles of the type submitted here. The significance of scientific articles is based on their substance, not on how many of them exist. These articles must be given meaningful consideration with regard to their substance rather than ducking the issue with no more than the passing remarks that they are not statistically significant in number. Similarly, the Examiner's statement that he "respectfully disagrees" that the post-Goldman users of lasers to treat varicose veins deliberately chose not to use Applicant's wavelengths is a statement with no basis or substantive content. The Examiner's personal views are irrelevant and immaterial. It is incumbent on the Examiner to state why he disagrees that Hennings Declaration Exhibits A-E do not show that the companies active in laser treatment of varicose veins deliberately chose not to use Applicant's wavelengths.

The Examiner also distorts Applicant's statement about the "purpose of Goldman". The purpose of Goldman is to treat varicose veins, not simply to heat them. Heating which does not result in vessel occlusion would be of no value.

With the foregoing in mind, we will review the rejections.

#### The Rejections Are In Error

Claims 1, 2, 6, 7, 25, 35-38, 40, 41 and 44-46 have been rejected under 35 U.S.C. § 103(a) as unpatentable over Goldman's '084 in combination with Sinofsky and Dew et al. As previously noted, Goldman is directed to RF heating of varicose veins and contains no more than a throw-away mention of lasers. No wavelength, energy or other information is given with regard to use of a laser

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and it is highly likely that Goldman had no idea of the mechanism by which lasers might operate in the treatment of varicose veins. As shown by the Proebstle article Geriak Exhibit B, laser treatment at wavelengths between 810 nm and 980 nm cause thrombolytic occlusion, **not** the shrinkage caused by the RF treatment of Goldman. Furthermore, as disclosed in the Proebstle article Geriak Exhibit C, it is steam bubble formation in the blood which is the mechanism by which laser treatment in this wavelength range accomplishes its purpose.

The choice of the wavelength of laser energy will be influenced by the substance which is the target for absorption of the laser energy. Thus, the laser energy used in the Proebstle articles targets blood as the chromophore so that steam bubbles will be formed. This was, of course, the reason why all of the commercial usages disclosed in the Hennings Declaration used laser energy with wavelengths in the range of 810 nm to 980 nm. Furthermore, the reason for targeting the blood was to minimize tissue damage outside the wall of the blood vessel. The Min article, Geriak Exhibit A, goes further and, on page 99, describes wavelengths higher than 980 nm, specifically 1,064 nm, as much less desirable.

The choice of laser wavelength for treatment of varicose veins was not and is not trivial or inconsequential. Thus, the Examiner's excursion into the prior art relating to the removal of atherosclerotic plaque as disclosed in Sinofsky and the healing procedure disclosed in Dew et al. to find laser treatments which have wavelength ranges which overlap those of Applicant is an out and out attempt to find bits and pieces of what is claimed by Applicant in various unrelated references and then attempt to patch them together.

It can be said without reservation that nobody of ordinary skill in the art would do this because the Navarro patent and the scientific literature found in Geriak Exhibits A-C plainly

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establish what the relevant scientific community really did in the post-Goldman period. What it did was to target the blood in the varicose vein. What Applicant did was to make a complete departure from the prior art and target the water in the blood vessel wall as the chromophore for laser energy in the range of about 1200 nm to 1800 nm. This was unobvious because it moved the target chromophore from the blood to the blood vessel wall and was contrary to the prior art belief that going to wavelengths as high as 1,064 nm was undesirable. Sinofsky and Dew have nothing to do with treating varicose veins and nothing to do with causing destruction of a blood vessel wall. Rather, Sinofsky wants to improve blood flow through a blood vessel and Dew is far afield in the healing arena. Thus, these rejections are in error.

Claims 3-5, 42 and 43 have been rejected as unpatentable under 35 U.S.C. § 103(a) over Goldman '084 in combination with Sinofsky, Dew and Roth. These claims recite a pull back device and Roth, in an entirely different context, also discloses a pull-back device. Applicant does not purport to be the inventor of a pull back device as such. The important point is that the Roth reference which is directed to the treatment of benign prostate hypoplasia, does nothing to cure the deficiencies in the attempted combination of Goldman, Sinofsky and Dew. Thus, the rejection of these claims is in error.

Claims 8 and 39 have been rejected under 35 U.S.C. § 103(a) as being unpatentable over Goldman '084 in combination with Sinofsky, Dew, and Conn. Conn teaches a diffusing tip. Applicant does not purport to be an inventor of a diffusing tip for a laser and points out that Conn does nothing to cure the deficiency of the attempted combination of Goldman with Sinofsky and Dew. Thus, claims 8 and 39 are patentable over the asserted combination of references.

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Claims 9-13 have been rejected as unpatentable under 35 U.S.C. § 103(a) over Goldman in view of Sinofsky, Dew and Makower. These claims recite the use of a thermal sensor to maintain a desired temperature. Makower discloses the use of infrared sensing to control heating of prostate tissue during the treatment of benign prostate hypoplasia. Applicant does not purport to be the first to use a thermal sensor to control a laser. What is significant is that Makower does not cure any of the deficiencies in the attempted combination of Goldman with Sinofsky and Dew and that the rejection of these claims is thus in error.

Claims 14-17 and 20-23 have been rejected under 35 U.S.C. § 103(a) as being unpatentable over Makower in combination with Roth and Dew. None of these references have anything to do with treatment of varicose veins. Makower and Roth are both directed to treatment of BPH and Roth discloses, at column 10, line 33, that the standard wavelength for an Nd:YAG laser is 1,064 nm. Makower discloses such a laser, but gives no information with regard to wavelength. The notion that one skilled in the art interested in treating BPH as disclosed in Makower and Roth which explicitly or implicitly disclose the standard wavelength of 1,064 nm would have any interest in the laser wavelength of Dew et al. which is used for an entirely different purpose is simply untenable. Furthermore, Makower and Roth cannot be combined. Makower is directed to a device which has a “locking” means and all of the claims in Makower are limited to a locking means. Roth, on the other hand, wants to pull his laser device through the tissue to more broadly distribute the energy which is incompatible with the locking system of Makower. Thus, this rejection is based on an absolutely improper combination of references.

Claim 19 has been rejected under 35 U.S.C. § 103(a) as unpatentable over Makower in view of Dew, Roth and Conn. This is, if it is possible, an even more improper combination than that of

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Makower, Dew and Roth. Conn teaches a diffusing tip for a laser. There is nothing in any of Makower, Dew or Roth to suggest that they have any interest in a diffusing tip, that it would be useful in any of their devices or that one skilled in the art would have any inclination to use a diffusing tip in those devices. Thus, this rejection is also in error.

Request for Examiner Affidavit under 37 CFR 1.104(d)(2)

37 CFR 1.104(d)(2) provides that “when a rejection...is based on facts within the personal knowledge of an employee of the Office,” the Applicant is entitled to request the affidavit of such employee.

In rejecting claims 3-5, 42 and 43 at page 4 of the Office Action dated February 12, 2007, the Examiner makes the statement that the “problem of tissue adhesion is notorious in the art” and that “official notice” of that problem is “hereby taken, thus producing a method such as claimed.” Applicant hereby requests an affidavit of the Examiner identifying such data or reference as may be relied upon by the Examiner in taking such “official notice”. In particular, such data or reference should be directed to a pull-back rate of between about 0.1 mm/sec to about 10.0 mm/sec and to beginning the retraction of the fiber optic laser prior to initiating delivery of the laser energy. In addition, it is believed that an explanation of why tissue adhesion has any relevance to this rejection should be explained.

Furthermore, it is believed that such an affidavit should also state the basis for the Examiner’s statement on page 3 of the Office Action dated February 12, 2007 that “the three articles submitted by Applicant’s do not constitute a statistically significant sample of all of the publications dealing with laser treatment of varicose veins and as such cannot be the basis for a claim such as made by Applicant.” It is believed that the affidavit should identify “all the publications dealing



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with laser treatment of varicose veins” to which the Examiner refers and set forth the basis for the Examiner’s position on what he considers a statistically significant sample would be and why such a sample would be needed.

### The Law

As noted above, In re Sullivan, \_\_\_\_ F.3d \_\_\_\_ (Fed. Cir. 2007), 2007 U.S. App. Lexis 20600, plainly holds that when evidence such as that embodied in Geriak Exhibits A-C and Hennings Exhibit A-E is presented, it must be given meaningful consideration. Applicant respectfully requests that the Board give this evidence meaningful consideration.

Furthermore, as noted in In re Sullivan, evidence “that the prior art teaches away from the claimed invention in any material respect” (Slip Opinion, page 9,) is probative evidence of unobviousness.

Plainly, the real world activity of those skilled in the art, as reflected in Navarro Patent No. 6,398,777, the scientific literature and the commercial literature presented by Applicant demonstrate that the prior art taught away from the use of laser energy having a wavelength in the range of about 1200 nm to about 1800 nm. Applicant chose a path shunned by others skilled in the art and his claimed invention is not obvious.

### ***Conclusion***

The invention claimed in this application is a departure from the prior art which uses laser energy having wave lengths from about 1200 nm to about 1800 nm to target the water in varicose vein wall tissue. This benefits the patient by minimizing collateral damage to the tissue surrounding the vein wall by localizing the hearing.

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The cited art is far afield. Goldman makes scant and non-enabling reference to the use of lasers, and is concerned with RF heating applicant's invention is a fundamental departure from the prior art relating to laser treatment of varicose veins. The Examiner has improperly refused to consider this prior art. The remaining cited art is directed to unrelated technology. The attempted reconstruction of the claimed invention from these disparate references is improper.

***Request for Oral Hearing***

Applicant hereby requests that an Oral Hearing be scheduled in this application. The Commissioner is hereby authorized to charge any fees associated to Deposit Account No. 15-0665.

***Fees***

The Commissioner is authorized to charge Orrick's Deposit Account No. **15-0665** for any fees required and credit any overpayments to said Deposit Account No. **15-0665**.

Respectfully submitted,

Orrick, Herrington & Sutcliffe, LLP

Dated: October 25, 2007

By:   
James W. Geriak, Reg. No. 20, 233

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# **APPENDIX 1**

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## ***APPENDIX***

1. An endovenous method of treating a varicose veins comprising the step of using a laser having a wavelength between about 1.2 and about 1.8  $\mu\text{m}$  to heat and shrink collagen in a varicose vein and to destroy the functionality of the varicose vein.
2. The method of claim 1 in which the laser energy is delivered with a fiber optic laser delivery device.
3. The method of claim 1 further comprising the following steps:  
inserting a fiber optic laser delivery device into the varicose vein;  
using a pullback device to retract the fiber optic laser delivery device through the varicose vein at a rate of between about 0.1 mm/sec and about 10.0 mm/sec while simultaneously delivering laser energy therefrom.
4. The method of claim 3 in which the fiber optic laser delivery device is retracted at a rate of between about 1.0 mm/sec and about 5.0 mm/sec.
5. The method of claim 3 in which the pullback device begins retraction of the fiber optic laser delivery device just prior to initiating delivery of the laser energy, thereby preventing the tip of the fiber, optic laser delivery device from sticking to the vessel wall.
6. The method of claim 1 further comprising the preliminary step of removing blood from the varicose vein prior to treatment with laser energy.
7. The method of claim 2 in which the fiber optic laser delivery device is introduced to the varicose vein through an introducer catheter.

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8. The method of claim 2 in which the energy delivered through the fiber optic laser delivery device is evenly distributed by using a diffuse radiating-tip mounted to the distal end of the fiber optic laser delivery device.

9. The method of claim 2 in which a non-contact thermal sensor is used to maintain a desired temperature.

10. The method of claim 9 in which the thermal sensor is used to maintain a desired coagulation temperature.

11. The method of claim 9 in which the thermal sensor is used to maintain a desired collagen shrinkage temperature.

12. The method of claim 2 further comprising the step of using the fiber optic laser delivery device as a thermal sensing element.

13. The method of claim 9 further comprising the step of modulating the laser power based on the sensed temperature to maintain the desired temperature.

14. A system for endovenous treatment of varicose veins comprising the following:  
a laser having a wavelength between about 1.2 and about 1.8  $\mu\text{m}$ ; and  
a fiber optic laser delivery device having a proximal end and a distal end, for delivery of laser energy from the distal end of the fiber optic laser delivery device to the inside wall of a varicose vein wherein the functionality of the varicose vein is destroyed and collagen in the varicosed vessel wall can be heated and shrunk.

15. The system of claim 14 further comprising a pullback device which retracts the fiber optic laser delivery device through the varicose vein at a rate of between about 0.1 mm/sec and about 10.0 mm/sec.

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16. The system of claim 14 further comprising means for administration of anesthesia to tissue surrounding the varicose vein, wherein the anesthesia causes swelling of the tissue surrounding the varicose vein which causes compression of the varicose vein in order to remove blood prior to treatment.

17. The system of claim 14 further comprising an introducer catheter in which an elongated lumen portion has a proximal end and a distal end, wherein the fiber optic laser delivery device is introduced to the introducer catheter through the proximal end and is introduced to the varicose vein through the distal end.

18. (cancelled)

19. The system of claim 17 further comprising a diffusing tip at the distal end of the introducer catheter for providing even distribution of energy radiating during treatment.

20. The system of claim 17 further comprising a diffusing tip at the distal end of the fiber optic laser delivery device for providing even distribution of energy radiating during treatment.

21. The system of claim 14 further comprising an non-contact thermal sensor.

22. The system of claim 21 further comprising a controller coupled to the thermal sensor for controlling the temperature in a region near the distal end of the fiber optic laser delivery device.

23. The system of claim 22 in which the controller modulates a power input to the laser for controlling the temperature in a region near the distal end of the fiber optic laser delivery device.

24. (cancelled)

25. An endovenous method of treating varicose veins with laser energy to heat and shrink collagen in the vein and to destroy the functionality of the varicose vein, the method comprising the following steps:

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inserting a laser delivery device into the varicose vein;  
delivering laser energy having a wavelength between about 1.2 and about 1.8  $\mu\text{m}$  to  
the varicose vein; and

retracting the laser delivery device through the varicose vein, thereby heating and  
shrinking the collagen in the vein and destroying the functionality of the varicose vein.

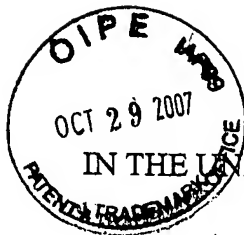
26. The method of claim 1 wherein the laser has a wavelength of about 1.32  $\mu\text{m}$ .
27. The system of claim 14 wherein the laser has a wavelength of 1.32  $\mu\text{m}$ .
28. The method of claim 25 wherein the laser energy has a wavelength of about 1.32.  $\mu\text{m}$ .
29. The method of claim 1 wherein said laser is a Nd:YAG laser.
30. The system of claim 14 wherein said laser is a Nd:YAG laser.
31. The method of claim 25 wherein said laser is a Nd:YAG laser.
32. The method of claim 1 wherein the laser energy preferentially heats the water in the  
wall of the vein.
33. The system of claim 14 wherein the laser is adapted to preferentially heat water.
34. The method of claim 25 wherein the laser energy preferentially heats the water in the  
wall of the vein.
35. A method of treating varicose veins, comprising:  
providing a beam of light comprising a wave length in the range of about 1200 nm to  
about 1800 nm; and  
delivering endovascularly the beam of light to target a chromophore comprising water  
in the wall of a targeted varicose vein to treat the vein.
36. (Cancelled)

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37. The method of claim 1 wherein said wave length is about 1320 nm.
38. The method of claim 35 further comprising delivering the beam of light via an optical fiber.
39. The method of claim 38 further comprising delivering the beam of light through a diffusing tip connectable to the optical fiber.
40. The method of claim 35 wherein the treatment comprises reducing the size of the targeted varicose vein.
41. The method of claim 1 further comprising heating the target chromophore to a temperature not greater than about 85° C.
42. (previously presented) The method of claim 38 wherein a pull-back device is used to position the optical fiber.
43. The method of claim 42 wherein the pull-back device withdraws the optical fiber from the targeted varicose vein at a rate of between about 0.1 mm/sec. and about 10.0 mm/sec.
44. The method of claim 35 in which blood is removed from the varicose vein prior to treatment with the beam of light.
45. The method of claim 35 wherein the beam of light has a power between about 1 to about 20 watts.
46. The method of claim 45 wherein the beam of light has a power of about 5 watts.



## **APPENDIX 2**



IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No. : 10/699,212 Confirmation No.: 2780  
Applicant : David R. Hennings et al.  
Filing Date : October 30, 2003  
Title : Endovenous Closure of Varicose Veins with Mid Infrared Laser  
Group Art Unit : 3739  
Examiner : David M. Shay  
Docket No. : 15487.4002  
Customer No. : 34313

Mail Stop AMENDMENT  
Commissioner for Patents  
PO Box 1450  
Alexandria, VA 22313-1450

**DECLARATION OF JAMES W. GERIAK**

I, James W. Geriak, do declare and say as follows:

1. I am one of the inventors named in the above-identified application.
2. Attached hereto as Exhibit A is a true and correct copy of *Endovenous Laser Treatment of Saphenous Vein Reflux: Long-Term Results*, by Robert J. Min, MD et al., JOURNAL OF VASCULAR AND INTERVENTIONAL RADIOLOGY, August 2003.
3. Attached hereto as Exhibit B is a true and correct copy of *Thermal Damage of the Inner Vein Wall During Endovenous Laser Treatment: Key Role of Energy Absorption by Intravascular Blood*, by T.M. Proebstle, MD et al., DERMATOLOGIC SURGERY, July 2002.

CERTIFICATE OF MAILING (37 CFR §1.8)

I hereby certify, pursuant to 37 CFR §1.8, that I have reasonable basis to expect that that this paper or fee (along with any referred to as being attached or enclosed) would be mailed or transmitted on or before the date indicated with the United States Postal Service with sufficient postage as first class mail on the date shown below in an envelope addressed to Mail Stop Amendment, Commissioner for Patents, PO Box 1450, Alexandria, VA 22313-1450.

Dated: November 22, 2005

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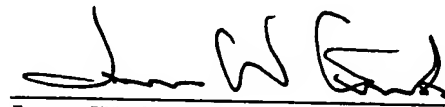
Sally Hartwell

Applicant : David R. Hennings et al.  
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4. Attached hereto as Exhibit C is a true and correct copy of *Endovenous treatment of the greater saphenous vein with a 940-nm diode laser: Thrombotic occlusion after endoluminal thermal damage by laser-generated steam bubbles*, by T.M. Proebstle, MD et al., JOURNAL OF VASCULAR SURGERY, April 2002.

Further, Declarant sayeth not:

I declare under penalty of perjury that the foregoing is true and correct. Executed this 22 day of November 2005 at Irvine, California.



James W. Geriak

# Endovenous Laser Treatment of Saphenous Vein Reflux: Long-Term Results

Robert J. Min, MD, Neil Khilnani, MD, and Steven E. Zimmet, MD

**PURPOSE:** To report long-term follow-up results of endovenous laser treatment for great saphenous vein (GSV) reflux caused by saphenofemoral junction (SFJ) incompetence.

**MATERIALS AND METHODS:** Four hundred ninety-nine GSVs in 423 subjects with varicose veins were treated over a 3-year period with 810-nm diode laser energy delivered percutaneously into the GSV via a 600- $\mu$ m fiber. Tumescence anesthesia (100–200 mL of 0.2% lidocaine) was delivered perivenously under ultrasound (US) guidance. Patients were evaluated clinically and with duplex US at 1 week, 1 month, 3 months, 6 months, 1 year, and yearly thereafter to assess treatment efficacy and adverse reactions. Compression sclerotherapy was performed in nearly all patients at follow-up for treatment of associated tributary varicose veins and secondary telangiectasia.

**RESULTS:** Successful occlusion of the GSV, defined as absence of flow on color Doppler imaging, was noted in 490 of 499 GSVs (98.2%) after initial treatment. One hundred thirteen of 121 limbs (93.4%) followed for 2 years have remained closed, with the treated portions of the GSVs not visible on duplex imaging. Of note, all recurrences have occurred before 9 months, with the majority noted before 3 months. Bruising was noted in 24% of patients and tightness along the course of the treated vein was present in 90% of limbs. There have been no skin burns, paresthesias, or cases of deep vein thrombosis.

**CONCLUSIONS:** Long-term results available in 499 limbs treated with endovenous laser demonstrate a recurrence rate of less than 7% at 2-year follow-up. These results are comparable or superior to those reported for the other options available for treatment of GSV reflux, including surgery, US-guided sclerotherapy, and radiofrequency ablation. Endovenous laser appears to offer these benefits with lower rates of complication and avoidance of general anesthesia.

J Vasc Interv Radiol 2003; 14:991–996

Abbreviations: GSV = great saphenous vein, RF = radiofrequency, SFJ = saphenofemoral junction

LOWER-extremity venous insufficiency is a common medical condition afflicting 25% of women and 15% of men in the United States (1). Gender, pregnancy, hormones, aging, and gravitational forces from prolonged standing or sitting are the most common factors that influence the appear-

ance or worsening of primary varicose veins (2,3). Although many people seek medical treatment for varicose veins because they find them unsightly, most people with varicose veins do experience symptoms (4,5). Unfortunately, symptoms of primary venous insufficiency are often not rec-

ognized by patients or their physicians. Characteristic leg complaints associated with varicose veins include aching pain, night cramps, fatigue, heaviness, or restlessness. Symptoms arise from pressure on somatic nerves by dilated veins and are typically worsened with prolonged standing, during the premenstrual period, or in warm weather (6). Left untreated, nearly 50% of patients with significant superficial venous insufficiency will eventually experience chronic venous insufficiency characterized by lower-extremity swelling, eczema, pigmentation, hemorrhage, and ulceration (7).

Great saphenous vein (GSV) reflux is the most common underlying cause of significant varicose veins. Traditional treatment of GSV reflux has been surgical removal of the GSV. Al-

From Cornell Vascular (R.J.M., N.K.), Weill Medical College of Cornell University, 416 East 55th Street, New York, New York 10022; and Zimmet Vein and Dermatology Clinic (S.E.Z.), Austin, Texas. Received January 24, 2003; revision requested April 11; revision received May 7; accepted May 8. From the 2003 SIR Annual Meeting. Address correspondence to R.J.M.; E-mail: rjm2002@med.cornell.edu

R.J.M. is a consultant to Diomed (Andover, MA), assisting in development of medical treatments and physician training. R.J.M. is coinventor and part owner of a patent on endovenous laser treatment of

veins, for which he receives royalties. R.J.M. and Cornell Vascular have paid for all medical equipment used in procedures relating to this study. S.E.Z. is a paid consultant to Diomed, Inc. (Andover, MA), assisting in development of medical treatments. S.E.Z. is also paid to assist in physician training. S.E.Z. purchased all medical equipment he used in connection with this study. The other author has not identified a potential conflict of interest.

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DOI: 10.1097/01.FVL0000082864.05622.E4

though surgical ligation and stripping of the GSV has been the most durable treatment, it is associated with significant perioperative morbidity. Less-invasive surgical treatments including high ligation of the GSV at the saphenofemoral junction (SFJ) have been attempted with the hope that gravitational reflux would be controlled while the vein is preserved for possible use as a bypass graft. Unfortunately, ligation of the GSV alone usually results in recurrent varicose veins (8). Even when high ligation has been combined with phlebectomy of varicose tributaries or retrograde sclerotherapy, recurrence has been the rule (9,10). Therefore, when it is determined that GSV reflux is the principal underlying problem, treatment should involve eliminating this source of reflux with ablation of any associated incompetent venous segments.

In 1999, Boné (11) first reported on delivery of endoluminal laser energy. Since then, a method for treating the entire incompetent GSV segment has been described (12,13). Endovenous laser treatment, which received approval from the US Food and Drug Administration in January 2002, allows delivery of laser energy directly into the blood vessel lumen. Non-thrombotic vein occlusion is accomplished by heating the vein wall with 810-nm-wavelength laser energy delivered via a 600- $\mu$ m laser fiber (Diomed, Andover, MA). Sufficient heating of the vein wall is necessary to cause collagen contraction and denudation of endothelium. This stimulates vein wall thickening, eventual luminal contraction, and fibrosis of the vein. The purpose of this study is to report on the long-term follow-up results of endovenous laser treatment for GSV reflux.

## MATERIALS AND METHODS

This prospective, nonrandomized, consecutive-enrollment study included 423 patients who underwent endovenous laser treatment of incompetent GSV segments with 810-nm diode laser energy delivered intraluminally for treatment of primary varicose veins. The study protocol was approved by the Weill Medical College of Cornell University Institutional Review Board. All patients gave written informed consent before treatment.

## Patient Selection

Directed history and physical examination, including duplex ultrasound (US) evaluation of the superficial venous system, was performed on limbs of subjects with varicose veins. Study inclusion criteria included varicose veins caused by SFJ incompetence with GSV reflux as demonstrated by duplex US imaging, age of at least 18 years, and ability to return for scheduled follow-up examinations for 12 months after endovenous laser treatment. Exclusion criteria included nonpalpable pedal pulses; inability to ambulate; deep vein thrombosis; general poor health; pregnancy, nursing, or plans to become pregnant during the course of participation in the investigation; and extremely tortuous GSVs that would not allow endovenous catheterization and passage of the laser fiber as identified on pretreatment venous duplex US mapping. After initial consultation and evaluation, subjects meeting the appropriate criteria were offered surgery versus endovenous laser treatment. Nearly all subjects chose endovenous laser over surgical ligation and stripping.

Five hundred four incompetent GSVs were treated with endovenous laser over a 39-month period. Five limbs were lost to follow-up. The remaining 499 limbs in 423 patients comprise the study population. This group consists of 352 women (83%) and 71 men (17%) ranging in age from 23 to 72 years, with a mean age of 42 years.

Follow-up ranged from 1 month to 39 months with a mean follow-up period of 17 months and an SD of 11 months. Aching leg pain was the most common presenting symptom, found in 87% of limbs. Overall, slightly more left legs ( $n = 263$ , 53%) were treated, and 76 patients (18%) were treated for bilateral GSV reflux. Pretreatment GSV diameter, measured in the upright position approximately 2 cm below the SFJ, ranged from 4.4 mm to 29 mm (mean, 11 mm; SD, 4.2 mm).

None of the patients in this series underwent concomitant ambulatory phlebectomy. All but seven patients underwent compression sclerotherapy treatment of distal varicose tributaries or associated telangiectasias at follow-up visits.

## Description of Technique

Duplex US was performed in the upright position to map incompetent sources of venous reflux and then to mark the skin overlying the incompetent portion of the GSV starting at the SFJ. After venous duplex mapping, a percutaneous entry point was chosen. This point may be where reflux is no longer seen or where the GSV becomes too small to access (usually just above or below knee level). With use of local anesthesia and sonographic guidance, the GSV was punctured. A 5-F introducer sheath was placed into the GSV over a guide wire and advanced past the SFJ into the femoral vein. Intraluminal position within the GSV was confirmed by aspiration of nonpulsatile venous blood and visualization with US.

The sheath was flushed and a 600- $\mu$ m laser fiber (Diomed) was inserted in the sheath and advanced up to the first site mark, indicating that the distal tip of the laser fiber was flush with the end of the sheath. The sheath was then withdrawn to the second site mark, exposing the distal 3 cm of the bare-tipped laser fiber. The sheath and fiber were pulled back together and positioned at the SFJ under US guidance. Position was confirmed by direct visualization of the red aiming beam of the laser fiber through the skin.

Tumescent local anesthesia consisting of 100–200 mL of 0.2% lidocaine neutralized with sodium bicarbonate, was administered along the perivenous space with use of US guidance. In addition to the anesthetic effects, properly delivered, this fluid serves two important functions: (1) it compresses and reduces the diameter of even the largest veins to provide vein wall apposition around the fiber tip with subsequent circumferential heating of the vein wall and (2) it provides a "heat sink" to minimize the possibility of heat-related damage to adjacent tissues. Figure 1a demonstrates the typical transverse sonographic appearance of the laser fiber and catheter seen centrally within an enlarged GSV located in the saphenous space. Proper and adequate delivery of tumescent anesthesia should result in fluid surrounding a compressed GSV as shown in Figure 1b.

The tip of the laser fiber was repo-

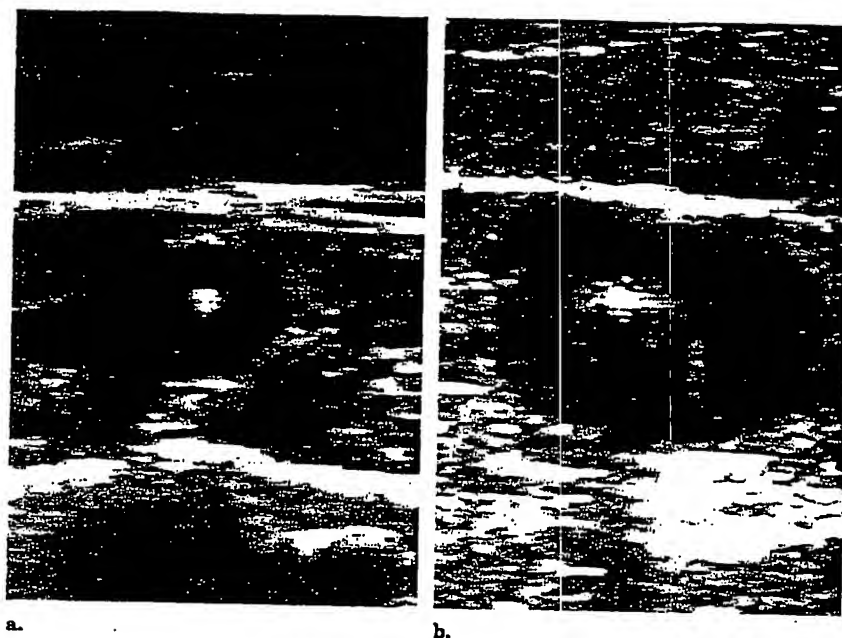


Figure 1. Duplex US (transverse view) demonstrating appearance of the GSV before and after proper delivery of tumescent anesthesia. (a) Intraluminal position of laser fiber and catheter within an enlarged GSV; (b) tumescent anesthesia delivered by echogenic needle tip adjacent to laser fiber and catheter with fluid surrounding the compressed GSV.

sitioned within the GSV 5–10 mm distal to the SFJ. Tip position was checked by US and direct visualization of the red aiming beam through the skin. Laser energy (810-nm diode laser, Diomed) was delivered at 14 W in continuous mode. The vein was treated from 5–10 mm below the SFJ to approximately 1 cm above the skin entry site. Length of GSV treated with endovenous laser ranged from 10 cm to 55 cm (mean, 35 cm; SD, 10 cm). The laser fiber was withdrawn at an average rate of 3 mm per second (18 cm per minute). Of patients treated with 14-W continuous mode ( $n = 276$ , or 55% of limbs), delivery of laser energy ranged from 25 seconds (at 358 J) to 187 seconds (at 2,615 J), with a mean of 123 seconds (SD, 47 sec) or 1,727 J (SD, 650 J).

A class II (30–40 mm Hg) full-thigh graduated support stocking or panty hose was worn for at least 1 week at all times except to sleep or to shower. Patients were instructed to ambulate and resume their normal daily activities immediately. Clinical and duplex US follow-up was obtained at 1 week, 1, 3, 6, 9, and 12 months, and then yearly.

Compression sclerotherapy treat-

ment of distal varicose tributaries was performed with use of sodium tetradecyl sulfate (0.3%–1% concentration). A detailed description of sclerotherapy technique is beyond the scope of this article but the approach used was the "French school" originally advocated by Tournay and more recently popularized in the United States by Goldman and other phlebologists (14). This technique relies on starting from the highest points of reflux and proceeding downward, and treating veins from the largest to the smallest. Compression stockings or panty hose were worn for at least 1 week after sclerotherapy treatments except to sleep or shower. Sclerotherapy treatments were performed at 4-week intervals, starting 1 month after endovenous laser ablation of the GSV.

#### Study Endpoints and Definitions

Duplex US criteria for successful treatment were the following: at 1-week follow-up, an enlarged non-compressible GSV, minimally decreased in diameter, with echogenic, thickened vein walls, and no flow seen within the occluded vein lumen on color Doppler interrogation; at 3- and

6-month follow-up, an occluded GSV with substantial (>50%) reduction in diameter; and at 1 year and beyond, complete disappearance of the GSV or minimal residual fibrous cord with no flow detectable. It is important to note that the expected appearance 1–2 weeks after endovenous laser is a slightly smaller GSV demonstrating wall thickening with absence of flow within the treated vein segment. The vein lumen is usually obliterated by the thickened wall, which has low-level echoes and is incompressible. This wall thickening should be differentiated from acute GSV thrombosis wherein the vein is also incompressible but the lumen is filled with anechoic acute thrombus. Several weeks after successful endovenous laser treatment, resolution of the acute inflammation in the vein wall should result in reduction in vein diameter. After several months, most of the treated vein segments will fibrose and be difficult to identify. Alternatively, superficial thrombophlebitis with GSV thrombus would result in recanalization of the vein. A longitudinal view of an enlarged, incompetent GSV is seen in Figure 2a. Figure 2b demonstrates the typical color Doppler appearance of a successfully treated GSV 1 year after endovenous laser treatment.

Clinical evaluation was performed on all subjects at 1 week, 1, 3, 6, 9, and 12 months, and yearly thereafter by the same physician (R.M.) who performed all the endovenous laser procedures. Patients were queried about symptomatic relief at follow-up visits, particularly improvement or resolution of lower-extremity pain believed to be associated with venous insufficiency. Improvement in the appearance of the leg, including reduction in visible varicosities, swelling, pigmentation, or other skin changes secondary to chronic venous insufficiency, were assessed by the patient and with direct comparison with pretreatment photographs obtained from all subjects undergoing treatment. Patients were evaluated for possible adverse reactions caused by endovenous laser treatment at each follow-up visit. Minor complications were defined as those that had no significant clinical sequelae, such as bruising. Major complications were defined as those necessitating an increased level of care, sur-



Figure 2. Color Doppler examinations (longitudinal views) of the GSV at the SFJ demonstrating successful occlusion after endovenous laser treatment. (a) Pretreatment evaluation demonstrates an enlarged GSV with reflux after distal calf compression; (b) 1-year follow-up examination shows typical "cul-de-sac" appearance of the proximal GSV with occlusion of the treated segment.

gery, hospitalization, or permanent adverse sequelae.

## RESULTS

Follow-up results ranging from 1 month to 39 months (mean, 17 months; SD, 11 months) were obtained in 499 of the 504 limbs treated with endovenous laser during the study period. Successful endovenous laser treatment, as defined earlier, was seen in 490 of 499 limbs (98%) at 1-month follow-up. Eight of nine GSVs requiring repeat endovenous laser were successfully closed with a second endovenous laser treatment. Continued closure of the treated GSV segments was noted at longitudinal follow-up at the following rates: 444 of 447 (99.3%) at 3 months, 390 of 396 (98.5%) at 6 months, 351 of 359 (97.8%) at 9 months, 310 of 318 (97.5%) at 1 year, and 113 of 121 (93.4%) at 2 years. Forty subjects have been followed for 3 years and no new recurrences were seen at 2 or 3 years that were not present at 1-year follow-up. In fact, all recurrences were noted before 9 months, with the majority seen by 3 months. This may indicate that these were not true recurrences but rather inadequate initial treatments.

Clinical examination correlated well with duplex US findings. All patients showed improvement in the appearance of the limb with disappearance or reduction in the size and number of visible varicosities. The typical appearance of varicose veins caused by incompetence of the SFJ with GSV reflux is shown in Figure 3a.

One month after endovenous laser treatment, relief of symptoms and significant improvement in the appearance of the varicose veins was noted (Fig 3b). By 6 months after initial treatment, pain was greatly improved or resolved in all treated limbs. Although symptomatic resolution and significant improvement in the appearance of the leg is usually noted after endovenous laser treatment alone, most patients will need additional complementary procedures (ie, sclerotherapy or phlebectomy) to fully realize the restorative benefits of treatment.

Bruising outside the puncture site was noted in 24% of limbs at 1-week follow-up. Bruising resolved in all subjects before 1-month follow-up. Ninety percent of subjects felt a delayed tightness peaking 4–7 days after laser treatment and lasting 3–10 days. This sensation, described as "pulling" along the course of the treated GSV, was not felt in the nine patients in whom initial treatment failed. Five percent of patients developed superficial phlebitis of varicose tributaries after endovenous laser occlusion of the GSV. Most cases required no treatment. Symptomatic patients were treated with graduated compression stockings and over-the-counter anti-inflammatory agents. All minor complications listed earlier resolved without sequelae. There have been no skin burns, paresthesias, cases of deep vein thrombosis, or other minor or major complications. The procedure was

well-tolerated by all subjects with strictly local anesthesia.

Overall treatment satisfaction was determined by asking subjects if they would recommend the procedure to a friend with similar leg vein problems, and 422 of 423 subjects (99.8%) indicated they would recommend the procedure.

## DISCUSSION

Percutaneous methods for treating incompetent GSVs are not new. Duplex-guided sclerotherapy for treatment of GSV reflux has been attempted, but long-term studies have failed to prove durability comparable to surgery (15–19). Initial attempts at damaging vein walls by electrocoagulation involved creation of a thrombus within the vessel lumen, ultimately resulting in recanalization (20–22). Early methods of intraluminal delivery of high-frequency alternating-current radiofrequency (RF) energy to treat GSV reflux were complicated by skin burns, saphenous nerve and peroneal nerve injury, phlebitis, and wound infection (23).

A more modern technique of the use of RF energy to eliminate saphenous vein reflux has been developed by VNUS Medical Technologies (Sunnyvale, CA). Early results reported from a multicenter trial demonstrated a reasonable degree of success with an overall failure rate of 10% at a mean follow-up of 4.7 months (13% in patients treated with RF alone and 5% in patients treated with RF plus high ligation of the GSV). Complications included transient paresthesias (thigh, 9%; leg, 51%), skin burns (3%), deep venous thrombosis (3%), and one pulmonary embolus (24). More recent studies have demonstrated success rates of 73%–90% with follow-up to 24 months in 21 limbs (25–27).

One of the limitations of our study is that it does not provide a blinded, randomized comparison of the various modern percutaneous methods available for treatment of GSV reflux, including RF and wavelengths of laser energy other than 810 nm. However, review of the literature allows some comparisons and raises some interesting areas for future study.

RF current damages tissue by resistive heating of structures in direct con-



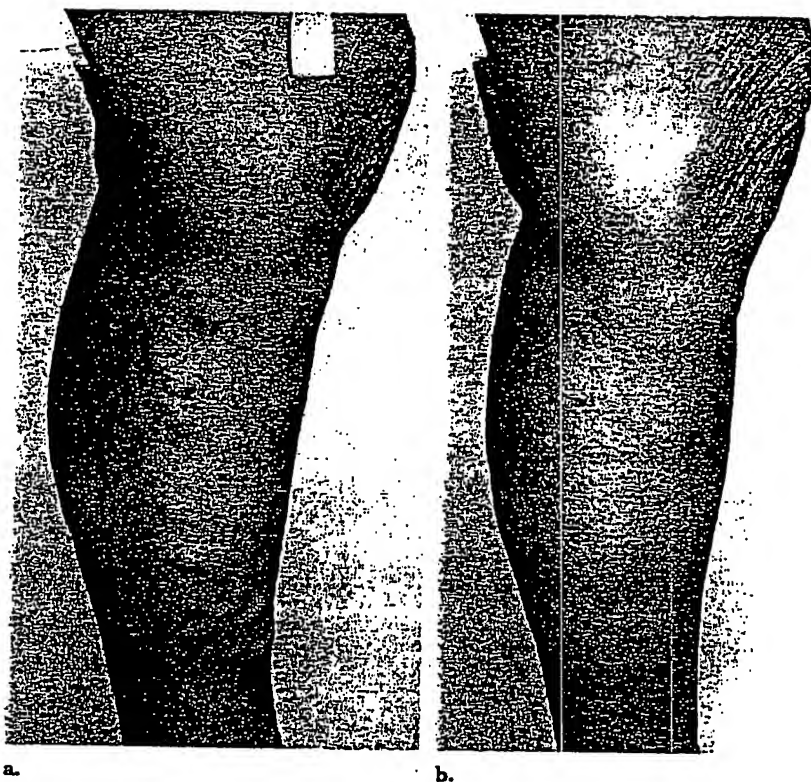


Figure 3. Significant improvement in appearance of varicose tributaries after endovenous laser treatment of an incompetent left GSV. (a) Typical appearance of varicose veins caused by GSV reflux; (b) the same leg 1 month after endovenous laser treatment.

tact with the electrodes. Deeper tissue planes are heated by conduction into normothermic tissue. Because the potential for heating of adjacent perivenous tissue is high, safe treatment with RF depends on proper delivery of adequate tumescent anesthesia. Effective use of tumescent anesthesia appears to have reduced the incidence of heat-related complications. In expert hands, the incidence of paresthesias after RF has occurred in as few as 8.5% of limbs within 1 week of treatment and decreased to 0.7% at 6 months (27). However, with less-experienced physicians, RF still has been complicated with heat-related adverse effects such as paresthesias (10% at 6 months) and skin burns (3.3%) (25).

Published experience with endovenous laser with use of wavelengths other than 810 nm is limited. A recent study by Chang and Chua (28) reported the use of 1,064-nm laser energy delivered endovenously for treatment of GSV reflux. Although this study reported a success rate of 96.8%

in 244 legs followed up to 28 months, significant complications were noted, including paresthesias (36.5%) and skin burns (4.8%). In addition to endovenous laser ablation, all patients in their study underwent surgical ligation and division of the proximal and distal ends of the treated GSV. In addition, patients treated with the 1,064-nm wavelength underwent spinal or general anesthesia rather than strictly local tumescent anesthesia (28).

In comparison, in our series of more than 500 limbs treated with 810-nm diode laser energy delivered endovenously, there have been no heat-related complications despite the high temperatures attained at the laser fiber tip. This may be explained by the following: (1) improved delivery and use of sufficient amounts of tumescent fluid in the proper tissue plane providing a protective thermal "sink;" (2) selective, homogeneous, and circumferential heating of the inner vein wall by absorption of 810-nm laser energy by blood lining the vein wall, as noted

in a recent study by Proebstle et al (29), rather than deeper penetration of laser energy and less-homogeneous heating from endovenous laser performed with wavelengths such as 1,064 nm, which are absorbed less by blood and more by water; and (3) faster rates of withdrawal and shallower depth of penetration of 810-nm laser energy, resulting in less damage to surrounding nontarget tissue compared with methods that use RF.

It has been suggested that a randomized controlled trial comparing outcomes of endovenous laser ablation of the saphenous vein to surgical ligation and stripping should be performed; however, such a study would be difficult given patients' overwhelming desire for minimally invasive treatments rather than surgery. Review of the existing surgical literature does provide some insight in assessing treatment durability. Multiple studies have shown that recurrence of varicose veins after GSV stripping occurs early (30), with 73% of limbs destined for recurrent varicosities at 5 years already having them at 1 year (31,32). Our results with endovenous laser have supported this, demonstrating that what is found on duplex imaging early is predictive of what will be seen later, with none of the treated patients developing recanalization of successfully occluded GSVs at 2 or 3 years that was not seen before 9 months.

Performing endovenous ablation of the GSV without dissection of the SFJ violates a cardinal rule in saphenous vein surgery that each of the tributaries must be individually divided. Surprisingly, the combined experiences with transcatheter endovenous ablation procedures have shown lower recurrence rates than with surgical ligation and stripping. Perhaps minimizing dissection in the groin and preserving venous drainage in normal, competent tributaries while removing only the abnormal refluxing segments does not incite neovascularization.

The understanding of venous disorders continues to improve with tremendous strides being made over the past decade. Readily available noninvasive diagnostic tests allow physicians to precisely map out abnormal venous pathways and identify sources of incompetence. Modern percutaneous methods of sealing incompetent veins



provide patients with alternatives to ligation and stripping for treatment of GSV reflux without the familiar morbidities associated with surgery (33,34). Given these recent advances, many physicians, when properly trained, will now be able to successfully diagnose and treat the whole spectrum of superficial venous insufficiency, offering acceptable options to the millions of people in the United States alone who have varicose veins but are unwilling or unable to undergo surgery.

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# Thermal Damage of the Inner Vein Wall During Endovenous Laser Treatment: Key Role of Energy Absorption by Intravascular Blood

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**BACKGROUND.** Despite the clinical efficacy of endovenous laser treatment (EVLT), its mode of action is incompletely understood.

**OBJECTIVE.** To evaluate the role of intravascular blood for the effective transfer of thermal damage to the vein wall through absorption of laser energy.

**METHODS.** Laser energy (15 J/pulse, 940 nm) was endovenously administered to explanted greater saphenous vein (GSV) segments filled with blood ( $n = 5$ ) or normal saline ( $n = 5$ ) in addition to GSVs under in vivo conditions immediately prior to stripping. Histopathology was performed on serial sections to examine specific patterns of damage. Furthermore, in vitro generation of steam bubbles by different diode lasers (810, 940, and 980 nm) was examined in saline, plasma, and hemolytic blood.

**RESULTS.** In saline-filled veins, EVLT-induced vessel wall injury was confined to the site of direct laser impact. In contrast, blood-filled veins exhibited thermal damage in more remote areas including the vein wall opposite to the laser impact. Steam bubbles were generated in hemolytic blood by all three lasers, while no bubbles could be produced in normal saline or plasma.

**CONCLUSION.** Intravascular blood plays a key role for homogeneously distributed thermal damage of the inner vein wall during EVLT.

W. ROTHER, PHD WAS AN EMPLOYEE OF DORNIER MEDTECH LASER GMBH. THE STUDY WAS SUPPORTED BY DORNIER MEDTECH LASER, WESSLING, GERMANY, AND BIOLITEC, JENA, GERMANY. T. M. PROEBSTLE, MD, MSc, M. SANDHOFER, MD, A. KARGL, MD, D. GÜL, MD, J. KNOP, MD, PHD, AND H. A. LEHR, MD, PHD HAVE INDICATED NO SIGNIFICANT INTEREST WITH COMMERCIAL SUPPORTERS.

RECENTLY, MINIMALLY invasive techniques have been clinically introduced for the effective treatment of varicose veins. In particular, VNUS closure<sup>1,2</sup> and endovenous laser treatment (EVLT)<sup>3-5</sup> have been shown to abolish reflux in the incompetent greater saphenous vein (GSV). Short-term efficacy has been reported as greater than 90%<sup>1,2</sup> and 95%,<sup>3-5</sup> respectively, comparing well with the results of classic surgery including high ligation and stripping of the GSV.<sup>2</sup> However, while the mode of action of VNUS closure has been studied in detail, the mechanisms of EVLT action are still not completely understood. It has been shown that EVLT, unlike VNUS, does not lead to occlusion of the vein by significant shrinkage of the vessel wall,<sup>6</sup> but instead causes a thrombotic occlusion of the laser-treated vein.<sup>5</sup>

Histopathologic examination of laser-treated veins revealed perforation of the vein wall at the site of direct laser impact and thermal damage of adjacent vein wall areas.<sup>5,6</sup> For the latter effect, laser-induced steam bubble formation has been postulated as the responsible mechanism,<sup>5</sup> implicating a putative role for intravascular blood serving as a chromophore absorbing the laser energy. In order, to further clarify the role of intravascular blood during EVLT, we performed comparative in vitro and in vivo experiments in the presence or absence of intravascular blood.

## Patients and Methods

### Administration of Laser Energy to GSV Samples

EVLT was applied as previously described in detail.<sup>5</sup> In brief, a 600  $\mu$ m bare fiber with an outer diameter of 1.00 mm was connected to a 940 nm diode laser. Under in vivo conditions (see Patients), the fiber was inserted below the knee into the surgically exposed GSV. The fiber was advanced proximally to the point of high ligation of the GSV and subsequently withdrawn in steps of about 3–5 mm while

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laser energy was applied.<sup>5</sup> Identical laser parameters were chosen for the in vitro experiments with GSVs (see below).

### *In Vitro Experiments With GSVs*

After classic varicose vein surgery of the GSV under tumescent local anesthesia,<sup>7,8</sup> the stripped vein segment was transferred to a saline bath at room temperature. The veins were cut into pieces 10 cm in length, and each piece was ligated at the proximal end before the laser fiber was inserted from the distal end. The vein was then filled either with heparinized blood (500 IU heparin/20 ml of blood) or with normal saline. After the distal end was ligated tightly around the laser fiber, single laser pulses of 15 J (15 W, 1 second) were delivered every 3–5 mm during stepwise withdrawal of the fiber tip. During the entire procedure the vein was bathed completely in normal saline solution. A total of 10 specimens, 5 filled with blood and 5 filled with normal saline during treatment, were subsequently fixed in formaldehyde, embedded in 1 mm rings in paraffin blocks, and studied histologically in routine hematoxylin and eosin stains on serial 5  $\mu$ m sections. Each section was evaluated with respect to signs of thermal damage at the site of direct laser impact, at the adjacent area, and at more distant sites. Particular attention was given to the vein wall opposing the site of direct laser impact.

### *Patients*

Two patients scheduled for classic varicose vein surgery under tumescent local anesthesia<sup>7</sup> consented to undergo experimental EVLT in the interval between high ligation and stripping of the GSV. One patient received EVLT with a blood-filled GSV. In the second patient, conditions were identical, apart from the fact that blood was washed out of the GSV and replaced by normal saline prior to EVLT. Complete replacement of blood by saline solution was confirmed visually by a flexible vascular fiberscope. The time interval between EVLT and invaginated stripping was 15 minutes. The vein was then cut into 2 cm sections, fixed in formaldehyde, and embedded in paraffin blocks for later histologic examination.

### *Laser-Generated Steam Bubbles in Normal Saline, Plasma, or Hemolytic Blood*

An in vitro setup to measure laser-generated steam bubble sizes was used as previously described.<sup>5</sup> Diode lasers with 810 nm, 940 nm, and 980 nm were used with appropriate 600  $\mu$ m fibers as provided by the manufacturers. Before starting the comparative experiments, the energy output of each device was calibrated at the fiber tip with a power meter. Before each experiment, the fiber tips were freshly cut to avoid secondary carbonization effects. Each laser wavelength was tested in tubes filled with normal saline, human plasma, and hemolytic blood by administration of pulses between 3 and 16 J. Plasma was obtained by centrifuga-

tion of heparinized blood for 20 minutes at 2000 g. Hemolytic blood was produced by replacing the removed plasma with equal volumes of distilled water.

### *Results*

EVLT was performed under in vitro conditions on GSV segments either filled with blood ( $n = 5$ ) or filled with normal saline ( $n = 5$ ). In addition, EVLT was performed in vivo after high ligation but before stripping of the GSV, in a vessel filled with either blood or normal saline. The generation of steam bubbles in normal saline, plasma, and hemolytic blood was examined for laser wavelengths of 810, 940, and 980 nm under in vitro conditions.

### *Pathologic Examination of GSV Segments Receiving In Vitro EVLT*

A minimum of 20 hematoxylin and eosin-stained serial sections of each vein segment were examined microscopically. Detectable changes of the vein wall, attributable to endovenous laser action, were highly reproducible. Figure 1 displays representative cross sections of laser-treated GSV segments. In saline-filled veins, vein wall damage was exclusively confined to the site of direct laser impact (Figure 1B), while adjacent regions (Figure 1A) and, in particular, the opposite side of the vein wall (Figure 1C) show virtually no signs of tissue damage. In contrast, pronounced thermal damage was detectable along the entire vein wall in blood-filled veins (Figure 1D,E), even at the vein wall opposite the laser impact (Figure 1F).

### *Pathologic Examination of EVLT Effects on Surgically Removed Veins*

The histopathologic examination of veins stripped after EVLT under in vivo conditions showed a similar pattern of thermal damage as the veins treated under in vitro conditions described above. Figure 2 displays representative sections of laser-generated complete perforations of the vein wall produced from the saline-filled (Figure 2A,B) or blood-filled (Figure 2D,E) vein. Again, the immediate site of laser impact exhibited a comparable extent of coagulative necrosis, regardless of whether the vein contained saline (Figure 2A) or blood (Figure 2D). However, even the immediately adjacent inner vein wall showed distinct differences in the extent of thermal damage (Figure 2A,B,D,E), with severe injury in the blood-filled vein and a virtually normal situation in the saline-filled vein. Also, the vein wall located at the opposite site of the laser impact showed heat damage in the blood-filled vein (Figure

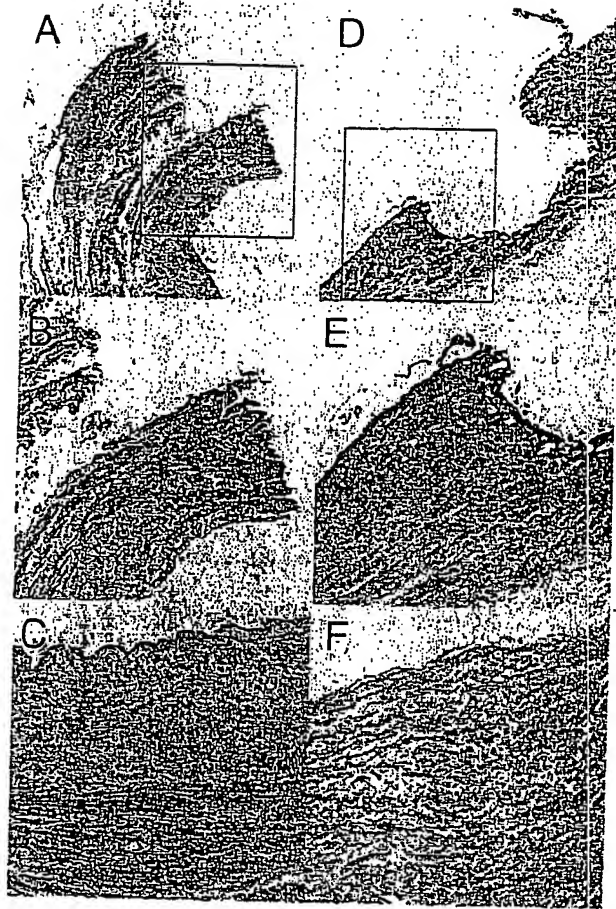


Figure 1. Representative hematoxylin and eosin sections of GSV segments after in vitro EVLT of A–C) saline filled veins or D–F) veins filled with heparinized blood. Under both conditions, direct laser impact causes perforation (A,B) or pronounced tissue ablation with focal coagulation necrosis at the immediate site of impact (D,E). In contrast to the saline-filled vein (A,B), the blood-filled vein exhibits more intensive and more remote injury to the adjacent vein wall areas (D,E). Likewise, superficial coagulative injury to endothelium, intima, and inner media are seen in vein wall areas on the opposite side of the laser impact in blood-filled veins (F), but are virtually absent in saline-filled veins (C). At most, slight tissue edema may be seen (C). Original magnification 55 $\times$  (A,D) and 140 $\times$  (B,C,E,F).

2F), while in the saline-filled vein, only minimal laser-induced thermal damage was observed (Figure 2C).

#### *Laser-Induced Steam Bubbles in Normal Saline, Plasma, and Hemolytic Blood*

For laser wavelengths of 810, 940, and 980 nm, steam bubble volumes were plotted against the administered pulse energy (Figure 3). If the tube was filled with normal saline or plasma, no wavelength was able to produce detectable steam bubbles with pulse energies up to 16 J (data not shown). In contrast, in tubes filled with hemolytic blood, steam bubble sizes showed an

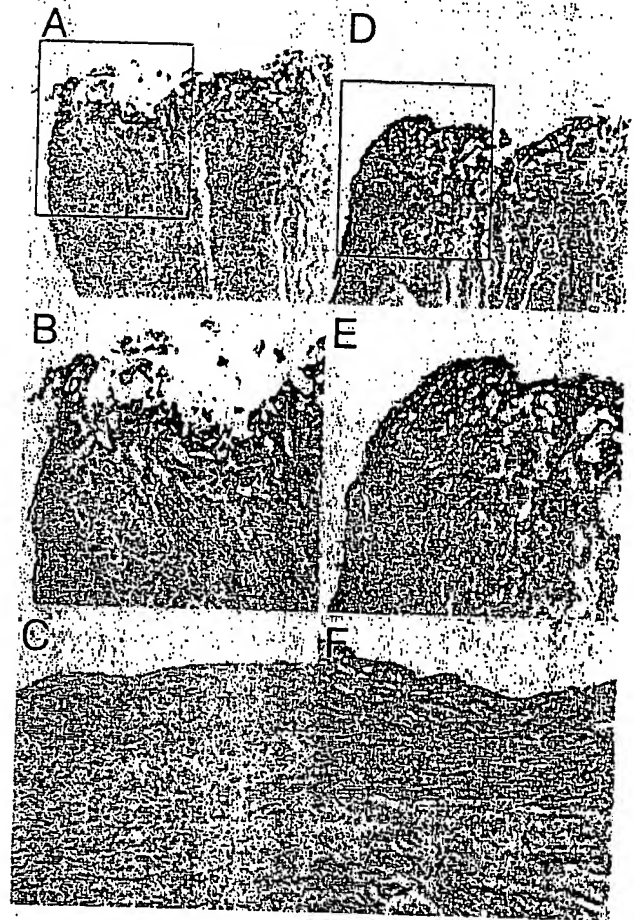


Figure 2. Histopathologic results of in vivo EVLT obtained from A–C) saline-filled or D–F) blood-filled veins. Arrangement of the panels as well as histomorphologic changes are identical to those described in Figure 1 and in the Results section of the manuscript.

almost linear proportionality with the administered laser energy. Note that no major difference could be detected between the three laser wavelengths. This indicates that the absorption of all three lasers by hemolytic blood is strong enough to transfer the energy completely into heat.

However, we found that this was true only if fresh-cut fiber tips were used for each experiment. Otherwise carbonization of the fiber tip led to extremely high tip temperatures, causing additional generation of energy through combustion of organic compounds of the hemolytic blood (data not shown).

#### **Discussion**

Despite growing acceptance and a rapid clinical introduction of EVLT, the underlying mechanism of action of this novel technique is still not fully understood. In a recent report of Weiss<sup>6</sup> it was demonstrated in elegant animal studies that endovenous radiofrequency

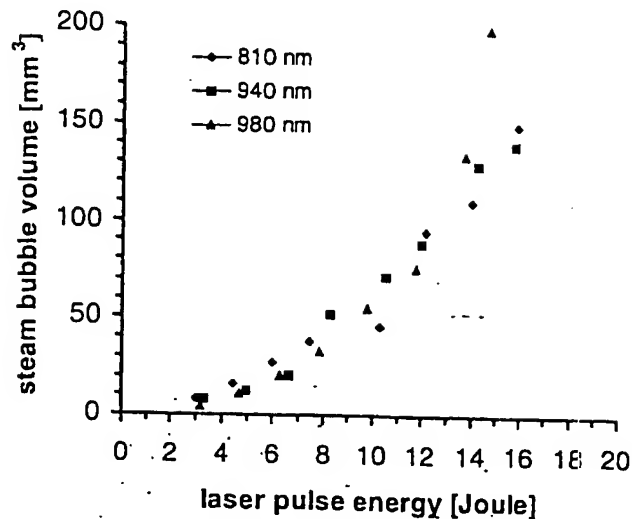


Figure 3. Laser-induced steam bubble volume in hemolytic blood plotted against delivered pulse energy for wavelengths of 810 nm (rhomboid), 940 nm (square), and 980 nm (triangle). No steam bubbles were produced with any of the experimental conditions in normal saline or plasma (data not displayed).

occlusion and EVLT have completely different modes of action. EVLT almost completely lacks the shrinkage effect of the vessels caused by prolonged exposure to moderate heat (85°C) in radiofrequency occlusion. Instead, EVLT causes perforation of the vein wall at the site of direct laser impact,<sup>5,6</sup> as a morphologic correlate for the consecutively observed perivenular ecchymoses.

In a previous report,<sup>5</sup> we proposed that laser-generated steam bubbles transfer a substantial amount of thermal damage to the vein wall during EVLT. These steam bubbles are created because of the high absorption of 940 nm laser energy in blood, with a technical penetration of only 0.3 mm. In water, this penetration depth is as much as 45 mm,<sup>9</sup> which is more than 100-fold deeper than in blood. Conversely, this implies that the absorption of 940 nm laser energy in water is less than 1% when compared to blood. Since under the particular topographic conditions of an endovascular laser fiber, a laser beam hits the vein wall within a markedly shorter distance than 45 mm, it can be concluded that heat generation by laser absorption cannot play a major role within a saline-filled vein. In this case, a laser beam of less than 1 mm diameter, with a fluence of more than 1500 J/cm<sup>2</sup>, directly hits the vein wall, leading to complete perforating ablation of tissue (Figures 1A,B and 2A,B).

Our experimental setup tested this hypothesis under in vitro and in vivo conditions, providing histopathologic evidence: In a saline-filled vein almost the entire amount of focused laser energy is transferred to a small area at the vein wall, while in a blood-filled

vein the thermal damage extends over a much wider topographic range of the inner vein wall, including the perilesional area and even areas opposite the immediate laser impact. This concordance between the in vitro and in vivo results suggests a sufficient correlation and validity of our in vitro model for the in vivo situation, despite the fact that under in vivo conditions the vein is much more compressed from outside by the presence of tumescent local anesthesia. However, one could speculate if a reduced, but still blood-filled, lumen of the vein could even facilitate laser-induced damage: relatively lower energies would suffice, because steam bubbles do not need to be generated in sizes that would be necessary to transfer homogenous damage to larger veins.

Evidence that blood plays not only a key role in absorption of 940 nm laser energy but also in absorption of 810 nm and 980 nm laser energy was provided by in vitro examination of steam bubble generation. While neither normal saline nor plasma were able to absorb laser energy substantially enough to generate steam bubbles, all three tested lasers produced comparable steam bubbles when exposed to hemolytic blood. Such steam bubbles, in all three laser systems, indicate that blood temperature passes the point of boiling at the site of the laser tip, thus transferring heat energy homogeneously to the inner vessel wall. The formation of these steam bubbles during EVLT could easily be monitored real time by duplex scanning, even allowing a continuous pullback of the laser fiber with the laser in continuous wave mode. One may speculate if with such a continuous pullback technique, perforations of the vein wall during EVLT could be avoided. However, a too-slow pullback velocity would certainly lead to a completely perforating longitudinal cut in the vein wall. Further experiments are needed on this topic. Therefore we hope that this improved knowledge about the exact mode of action of laser-induced vein damage may contribute to an improvement of endovenous laser treatment.

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# Endovenous treatment of the greater saphenous vein with a 940-nm diode laser: Thrombotic occlusion after endoluminal thermal damage by laser-generated steam bubbles

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**Purpose:** Despite a rapid spread of the technique, very little is known about the laser-tissue interaction in endovenous laser treatment (EVLT). We evaluated EVLT of the incompetent greater saphenous vein (GSV) for efficacy, treatment-related adverse effects, and putative mechanisms of action.

**Methods:** Twenty-six patients with 31 limbs of clinical stages C<sub>2-6</sub>, E<sub>1</sub>, A<sub>2-3</sub>, P<sub>2</sub> with incompetent GSV proven by means of duplex scanning were selected for EVLT in an outpatient setting. A 600- $\mu$ m fiber was entered into the GSV via an 18-gauge needle below the knee and proceeded to the saphenofemoral junction (SFJ). After infiltration of tumescent local anesthesia, multiple laser pulses of 15 J energy and a wavelength of 940 nm were administered along the vein in a standardized fashion. D-dimers were determined in peripheral blood samples 30 minutes after completion of EVLT in 16 patients and on postoperative day 1 in 20 patients. One GSV that was surgically removed after EVLT was examined by means of histopathology. Additionally, an experimental in vitro set-up was constructed as a means of investigating the mechanism of laser action within a blood-filled tube.

**Results:** A median of 80 laser pulses (range, 22-116 laser pulses) were applied along the treated veins. On days 1, 7, and 28, all limbs except one (97%) showed a thrombotically occluded GSV. In one patient, the vessel showed incomplete occlusion. The distance of the proximal end of the thrombus to the SFJ was a median 1.1 cm (range, 0.2-5.9 cm) in the remaining patients. Adverse effects in all 26 patients were ecchymoses and palpable induration along the thrombotically occluded GSV that lasted for 2 to 3 weeks. In two limbs (6%), thrombophlebitis of a varicose tributary required oral treatment with diclofenac. D-dimers in peripheral blood were tested with normal results in 14 of 16 patients 30 minutes after completion of the procedure and elevated results in 7 of 20 patients at day 1 after EVLT. However, an increase of D-dimers from day 0 to day 1 was observed in 15 of the 16 patients undergoing tests 30 minutes after EVLT and on day 1. The 940-nm laser was demonstrated by means of in vitro experiments and the histopathological examination of one explanted GSV to act by means of indirect heat damage of the inner vein wall.

**Conclusion:** EVLT of the GSV with a 940-nm diode laser is effective in inducing thrombotic vessel occlusion and is associated with only minor adverse effects. Laser-induced indirect local heat injury of the inner vein wall by steam bubbles originating from boiling blood is proposed as the pathophysiological mechanism of action of EVLT. (J Vasc Surg 2002; 35:729-36.)

For many patients of clinical stages C<sub>2</sub> to C<sub>6</sub> with proven incompetence of the saphenofemoral junction (SFJ) and refluxes along the greater saphenous vein (GSV), the standard surgical treatment still is high ligation of the vessel and its tributaries at the level of the SFJ, with subsequent stripping of the incompetent part of the GSV. In the last decade, less-invasive techniques have been further developed, particularly the use of tumescent local anesthesia

facilitated ambulatory phlebectomy<sup>1,2</sup> or high ligation and stripping of the GSV.<sup>3-5</sup> In the last few years, a radio-frequency heating technique has been developed as an endoluminal approach with a distal, microsurgical vein access producing excellent cosmetic results.<sup>6</sup> One distinct major difference compared with classic varicose vein surgery is that endoluminal radio-frequency solely occludes the GSV without affecting tributaries at the level of the SFJ. Such a strategy is particularly remarkable, because it is generally accepted that recurrent varicose veins after surgery often have their origin in residual tributaries of the SFJ or in a residual saphenous stump. A recent study that suggested that, at least with short-term follow-up, extended ligation at the SFJ did not add much when compared with endoluminal closure of the GSV alone<sup>7</sup> raised a very controversial discussion. More recently, a similar minimally invasive technique, endovenous laser treatment (EVLT) of the GSV has been introduced,<sup>8</sup> and, in contrast to transcutaneous laser treatment of reticular veins and venulectasias,<sup>9,10</sup> we are only starting to learn about the

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Competition of interest: Dr Rother, who constructed the experimental set-up for in-vitro testing, is an employee of Dornier MedizinLaser GmbH, Germering, Germany.

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Table I. Characteristics of 31 treated limbs of 26 patients who underwent endovenous laser treatment, according to the CEAP classification

	Number of limbs (%)
Clinical stage	
C2 Varicose veins > 4 mm	31 (100)
C3 Edema	25 (81)
C4 Skin changes	11 (35)
C5 Healed ulcer	0 (0)
C6 Active ulcer	4 (13)
Etiology	
Primary	31 (100)
Secondary	0 (0)
Anatomy	
Superficial veins	31 (100)
Perforator veins	17 (55)
Cockett II/III	14 (45)
Sherman	3 (10)
Deep veins	0 (0)
Pathology	
Reflux	31 (100)
Obstruction	0 (0)

efficacy, adverse effects, and mode of action of this novel approach.

This study was conducted to obtain more detailed clinical and histopathological data on the application of EVLT in patients with clinical stages C<sub>2-6</sub>, E<sub>p</sub>, A<sub>s,r</sub>, P<sub>R</sub>, including an incompetent GSV. An *in vitro* set-up was developed and used as a means of further clarifying the mode of action of EVLT on the inner vessel wall.

## METHODS

**Patients.** Patients were selected from our phlebology clinic as they came in for evaluation of specific complaints. As part of their routine examination, all patients underwent functional testing, including duplex scanning (Sonosite 180 plus, 4med, Erlangen, Germany). When a clinical stage C<sub>2</sub> to C<sub>6</sub> with an incompetent SFJ and reflux in the GSV were revealed by means of the phlebological examination, and thus an indication for high ligation and stripping was presented, patients were asked to choose between classic varicose vein surgery or EVLT. Only three of 29 patients preferred classic varicose vein surgery, whereas 26 patients chose EVLT. However, patients made this decision after reading information and an additional personal discussion with the physician about EVLT, which, in contrast to surgery, so far has no long-term follow-up, and the possible need for additional treatment measures, including classic surgery, later. Apart from the incompetent GSV, other incompetent superficial veins and perforator veins were tolerated, but not treated simultaneously to EVLT. Patients with secondary varicosis with deep vein reflux or deep vein obstruction were not able to undergo EVLT (Table I). All patients gave written informed consent in accordance to the Helsinki declaration.

**Administration of laser energy.** The whole EVLT procedure was exclusively limited to the GSV, and no

additional measures like mini-phlebectomy or sclerotherapy were used as a means of treating tributaries of the GSV simultaneously. Roughly, the protocol was adapted from the paper of Navarro et al.<sup>8</sup> After duplex scanning-guided puncture of the GSV below the knee with an 18-gauge venous catheter (Vasofix, Braun, Melsungen, Germany), a J-tip guidewire (0.035-in, Medex Medical, Rossendale, UK) was advanced by means of duplex scanning control toward the SFJ. A 5F angio catheter (Infiniti, 100 cm, 0.97 mm, vertebral, Cordis Europe, 9301 LJ Roden, Netherlands) was shortened at the tip with a scalpel by approximately 5 cm to allow passage of the bare fiber more easily. The catheter was then forwarded over the guidewire until its tip was located approximately 1 cm distal to the SFJ. The guidewire was then removed and replaced by a 600-μm bare fiber with an outer diameter of 1.00 mm (Type D-6100-BF, Dornier MedizinLaser GmbH, Gemmering, Germany) connected to a 940-nm diode laser (Medilas D, Dornier MedizinLaser GmbH). With duplex scanning control, the laser fiber tip was passed through the tip of the angio catheter, thus extruding approximately 6 to 8 mm, with a final distance toward the SFJ of 1 to 2 cm. The correct location of the fiber tip could also be verified visually: in the darkened operation theater, the red (645 nm, 1 mW) pilot beam was detectable transcutaneously. Tumescence local anesthesia was then infiltrated along the GSV from the SFJ down to the point of access, as described elsewhere,<sup>3</sup> and given 5 minutes to establish the anesthetic effect before the start of the laser treatment. Laser energy was delivered in a pulsed fashion with a 1-second on and a 2-second off period. During the on period, 15 J of laser energy were delivered with a power of 15 W. During the off period, the fiber tip was retracted 5 to 7 mm. This cycle was repeated until a distance of 1 cm to the puncture site of the GSV was reached. In this manner, the laser treatment of the entire GSV lasted 3 to 5 minutes. Subsequently, the catheter was removed, and the patient received a full thigh class II compression stocking, resembling an ankle pressure of 30 mm Hg, and was advised to walk immediately. Additionally, as a precaution without any further rationale, low-molecular-weight heparin was administered subcutaneously for 5 days for thrombosis prophylaxis (Fragmin P, Pharmacia & Upjohn, Erlangen, Germany).

**Concomitant duplex ultrasound scanning examination.** All patients underwent duplex ultrasound scanning examinations before EVLT, during EVLT, and after EVLT on days 1, 7, and 28. During the course of the examinations, patients underwent scanning for refluxes in superficial veins, in the deep vein system, and also in perforating veins. Patients with an incompetent or occluded deep vein system were excluded from EVLT. Concomitant incompetent perforator veins or pathological findings in the superficial vein system were recorded, but did not prevent patients from receiving EVLT if the GSV was open and incompetent from the SFJ down to below the knee.

During EVLT itself, duplex scanning was particularly helpful in identifying the GSV at the puncture site, when necessary after full length down-scanning of the GSV from



the groin or up from the ankle. Duplex scanning was further an important means of localizing the precise position of the laser tip close to the SFJ before administration of tumescent local anesthesia, because afterward, because of the massive subcutaneous fluids, recognition of anatomical structures was almost impossible.

With scheduled duplex ultrasound scanning control examinations on days 1, 7, and 28, a full-length scanning of the treated vein was included as a means of demonstrating homogeneous thrombotic occlusion. Occlusive thrombosis was supposed when the vein was completely filled by an incompressible hypoechogenic mass and when no fluxes were detected within the vessel lumen. Similarly, in the region of the SFJ, the proximal ending of the thrombus was determined by means of compression and detection of fluxes. The distance of the proximal thrombus ending toward the junction with the deep femoral vein was measured. At day 28, the hypoechogenicity of the thrombus had almost disappeared. However, the lack of fluxes and the remaining incompressible vessel still allowed sufficient conclusions. Additional scanning of the deep vein system excluded a thrombotic affection there.

**Testing for D-dimers in peripheral blood.** After detection of EVLT-induced thrombotic occlusion, rather than an immediate closure of the GSV, we scheduled D-dimer testing for every patient. With the exception of the first six patients, D-dimer values (Tinaquant D-dimer, Roche Diagnostics, Mannheim, Germany) were scheduled to be determined from blood samples obtained 30 minutes and 1 day after the EVLT procedure. According to the manufacturer's data sheet, D-dimer values below 0.50 mg/L were considered to be within normal limits. However, because of technical reasons, blood sampling failed in four patients 30 minutes after EVLT.

**Histopathologic examination.** One patient gave informed consent to undergo EVLT as part of his routine varicose vein surgery procedure, which included extended high ligation of the SFJ and subsequent stripping of the incompetent parts of the GSV. EVLT was administered immediately after completion of extended high ligation, but before stripping of the GSV. The treated vein was left in place for another 15 minutes and then removed by means of stripping. The removed vein was photodocumented (Fig 1, A) and histopathologically examined with hematoxylin and eosin staining.

**Mechanism of laser action.** As a means of evaluating the mechanism of action of the 940-nm laser beam within the vein, an experimental set-up was designed (Fig 3, A). A silicone tube with an inner diameter of 6 mm was connected to a transparent tube with an inner diameter of 2 mm. The tube system was then filled with heparinized blood. From the opposite side, the laser fiber was inserted into the middle of the silicone tube. Different amounts of laser energy were then applied by means of variation of either laser power or pulse duration. With each laser pulse, the extension of the volume within the system was assessed by documenting the change in the blood level within the 2-mm tube. A cylindrical volume calculates as  $V = h \times \pi r^2$

(eg, if a laser pulse produces a movement of the blood level of  $h = 54$  mm, the laser generated steam volume calculates as  $V = 54 \text{ mm} \times \pi [1 \text{ mm}]^2 = 170 \text{ mm}^3$ , corresponding to a steam bubble length of 6 mm in a tube with a diameter of 6 mm). The temperature of the steam bubble is supposed to be close to 100° C and, once generated, should stay on this level constantly throughout its increase of volume, as it is known in the physics of phase transitions.

## RESULTS

Twenty-six patients, 21 with unilateral and 5 with bilateral incompetent GSV, received EVLT by means of a 940-nm diode laser with tumescent local anesthesia. Nineteen patients were women (73%), and seven patients were men (27%), with 22 and 9 limbs treated, respectively. The median age of the patients was 57 years (range, 27-83 years). Before treatment, the median diameter of the GSV was 6.0 mm (range, 4.0-9.9 mm) at the level of the SFJ. In our relatively small cohort with a spectrum of clinical stages (Table I), the GSV diameter did not correlate with the body mass index of the patient (data not shown), the median of which was 26.6 (range, 20.0-39.7). The median amount of infiltrated tumescent local anesthesia was 650 mL per limb (range, 250-1000 mL).

**Technical skills.** Initially, before the use of duplex scanning for guided puncture of the GSV, access to the GSV failed in two of seven patients. These two patients underwent subsequent classic surgery. In four additional cases, insertion of the guidewire from below the knee to the SFJ was not possible in one step because of pronounced tortuosity of the GSV. In three of these four cases, an additional puncture of the GSV approximately 15 cm above the knee allowed treatment in two parts. In one case, EVLT was limited to the proximal 20 cm of the GSV because of the technical inability to obtain access to the more distal part of the GSV.

However, in all cases, duplex scanning-controlled placement of the fiber tip was achieved within a distance of 1 to 2 cm distal from the SFJ. In patients who were not overtly obese, this position could be visualized by means of transcutaneous illumination of the pilot laser beam. In our series of 31 limbs in 26 patients, this was true in four limbs of three male patients with a body mass index between 31.5 and 39.7. However, even in those obese patients, transcutaneous detection of the laser pilot beam was possible after applying gentle pressure to the overlying skin.

**Effects of endovenous laser treatment.** During step-wise removal of the laser fiber, a median of 80 pulses (range, 22-116) of 15 J energy each were delivered, corresponding to a distance of 5 to 7 mm between laser pulses.

On days 1, 7, and 28 after treatment, thrombotic occlusion of the GSV was noted in all cases. In 30 of 31 limbs (97%), the thrombotic occlusion was complete from the distal puncture site, reaching proximally up to a median distance of 1.1 cm (range, 0.2-5.9 cm) from the SFJ. In one limb, the proximal occlusion of the GSV failed over a length of 20 cm despite complete occlusion of more distal parts of the GSV. The diameter of the GSV at the SFJ was 9.9 mm

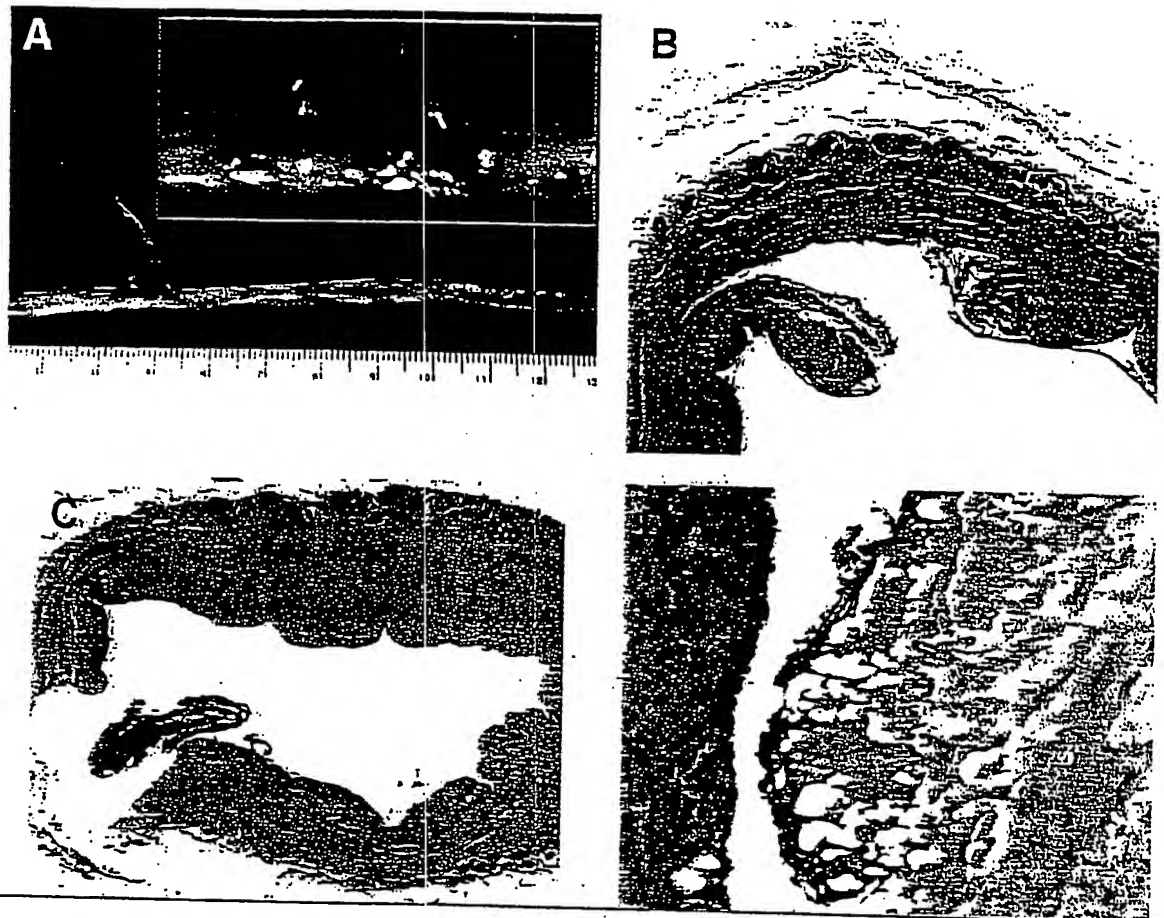


Fig 1. Macroscopic and microscopic hematoxylin and eosin-stained histopathologic examination of a GSV that has undergone EVLT before stripping. A, Outer surface of the endovenously laser-treated GSV. Dark spots resembling carbonization, or even full perforation of the vein wall, were caused by direct impact of the 940-nm laser beam. B, Longitudinal tear next to a non-perforating laser hit. C, Vein wall disruption caused by direct laser impact. D, High magnification of the margin area of vein wall disruption showing pronounced thermal damage, including carbonization.

and, therefore, the largest diameter of the whole series. Additionally, in this patient, we found by means of duplex scanning control a large caliber tributary with high blood flow feeding the GSV at the distal open point.

**Adverse effects.** After the local anesthetic effect subsided after EVLT, slight to moderate local pain was reported by all patients over the treated vein. Also, moderate ecchymoses, most likely caused by laser-induced perforation of the vein wall, could be observed in every patient at the inner thigh and knee region from the next day to approximately 2 weeks later. However, these ecchymoses were not as pronounced as they are usually with classic varicose vein surgery, and no hematoma was found. For the first 2 to 3 weeks after EVLT, also a slightly shorter period than frequently observed with classic surgical procedures, an induration was palpable along the treated GSV, and this was experienced by the patients as slight to moderate pain during extended movement of the leg. A thrombophlebitic reaction developed within an untreated varicose tributary at

the distal thigh in two patients 2 and 5 days after EVLT. Oral treatment with diclofenac (75 mg, slow release, three times a day) resulted in immediate pain control. Hyperpigmentation developed in one patient over the thrombotically occluded GSV, which was still visible at 4 weeks after EVLT. All other patients were free of adverse effects at 4 weeks after the procedure. No other adverse effects or complications were reported.

**D-dimers in peripheral blood.** In 16 patients, D-dimer levels in peripheral blood were evaluated immediately after EVLT, and in 20 patients, blood samples were drawn on day 1 after EVLT (Table II). D-dimer levels were tested with normal results in all samples except one obtained 30 minutes after EVLT, with a median value of 0.39 mg/L (range, 0.09-0.80 mg/L). When D-dimer levels were tested at day 1 after EVLT in 20 patients, a median of 0.43 mg/L (range, 0.24-1.73 mg/L) was found. However, only seven blood samples showed D-dimer levels exceeding the upper limit of 0.50 mg/L. Although the

Table II. D-dimer levels in peripheral blood of patients who underwent endovenous laser treatment

	30 minutes after EVLT	1 day after EVLT	Ratio 1 day/30 min
Patients with 1 limb treated	Median 0.30 mg/L (range 0.09-0.80) n = 13	Median 0.33 mg/L (range 0.24-1.73) n = 16	Median 1.39 (range 0.88-3.67) n = 13
Patients with 2 limbs treated	Median 0.45 mg/L (range 0.44-0.48) n = 3	Median 0.68 mg/L (range 0.50-0.91) n = 4	Median 1.82 (range 1.15-2.02) n = 3
All patients	Median 0.39 mg/L (range 0.09-0.80) n = 16	Median 0.43 mg/L (range 0.24-1.73) n = 20	Median 1.43 (range 0.88-3.67) n = 16

EVLT, Endovenous laser treatment.

absolute values remained mostly within normal limits, D-dimer levels were shown by means of intraindividual evaluation to increase from day 0 to day 1 in 15 of 16 patients who underwent both tests. The median increase ratio was 1.43 (range, 0.88-3.67), reflecting the process of thrombotic occlusion of the GSV. When separating the patients who received unilateral EVLT from patients who had a bilateral procedure (Table II), it looks as if patients with both limbs treated did not present the very low D-dimer values that are occasionally observed in patients with one limb treated. This observation might relate to two thrombotic processes instead of one, but also might be influenced by the thrombotic process having proceeded somewhat more in the first limb of those patients with bilateral EVLT. Unfortunately, the numbers are small in Table II and therefore do not warrant statistical analysis.

Pathologic examination of the endovenous laser treatment stripped vein. Macroscopically, the vein wall showed reddening, carbonization, or even perforation at those sites where the fiber tip was closest to the vein wall during delivery of laser energy (Fig 1, A). Either gross vein wall destruction associated with direct impact of the laser beam (Fig 1, B-D) or less pronounced heat-mediated vein wall injury (Fig 2, B, C) was demonstrated by means of microscopical examination of corresponding hematoxylin and eosin-stained slides. The heat injury demonstrated in Fig 2, B and C, was consistently detectable along the distance of 5 to 7 mm of vein wall, between the direct impact of two laser impulses, and is, in our opinion, the basis of a subsequent homogeneous thrombotic occlusion of the vessel. At those sites of direct laser action, the most destructive patterns of tissue damage can be observed: perforating and non-perforating vaporization of the vein wall, carbonization of the adjacent tissue margins, and intimal tear in response to the explosion-like delivery of high energy densities, called photo-disruption. However, because a stripping was performed after EVLT, some of the destruction observed, like intimal tears, may originate from the stripping procedure itself.

Mechanism of action of the 940-nm diode laser. Administration of different amounts of laser energy in the in vitro set-up was used as a means of evaluating the putative mechanism of laser action within the vein (Fig 3).

During the experiments with heparinized blood in a silicone tube, we observed that a steam bubble formed during delivery of laser energy, and it collapsed immediately after discontinuation of the laser pulse. When we plotted the maximum volume of the laser-generated steam bubble against the amount of laser energy delivered, it showed a linear correlation (Fig 3, C). As calculated in the Methods section, a typical laser pulse with an energy of 15 J produced a steam bubble of approximately 6 mm in a 6-mm diameter vessel. As shown in Fig 3, C, the formation of a steam bubble required a threshold energy of about 1.5 J. This threshold energy is needed to heat up the surrounding blood until it reaches boiling temperature. A laser pulse energy below this level would only heat the blood, without any steam bubble formation.

## DISCUSSION

The principal finding in this study is that EVLT with a 940-nm diode laser system, when performed under tumescent local anesthesia, is a clinically feasible and well-tolerated technique. Because of vein access via an 18-gauge needle, it is a truly minimal invasive procedure, leaving a virtually invisible scar on the patient's skin.

The efficacy of EVLT in obtaining early occlusion of the GSV is very satisfactory. Even if these are very early results, immediate closure rates of 97% in our series and 100% reported by another group with the 810-nm diode laser<sup>8</sup> provide a rationale for further evaluating this new method.

A major emphasis of this study was placed on the mode of action of this novel technique: technically, the depth of penetration of a 940-nm laser beam into blood is only approximately 0.3 mm.<sup>11</sup> Also, the laser beam remains focused to a very small spot after leaving the fiber tip. Although these characteristics of the laser beam could explain a focal perforation of the vein wall (Fig 1, C, D) immediately adjacent to the fiber tip, this would not adequately explain the widespread injury to the vein wall observed in the vicinity of the perforation sites (Fig 2, B, C). With our in vitro set-up, we could identify steam bubble formation at the laser tip (Fig 3, B). The volume of the laser-generated steam bubble correlated directly to the laser energy (Fig 3, C). Because such a

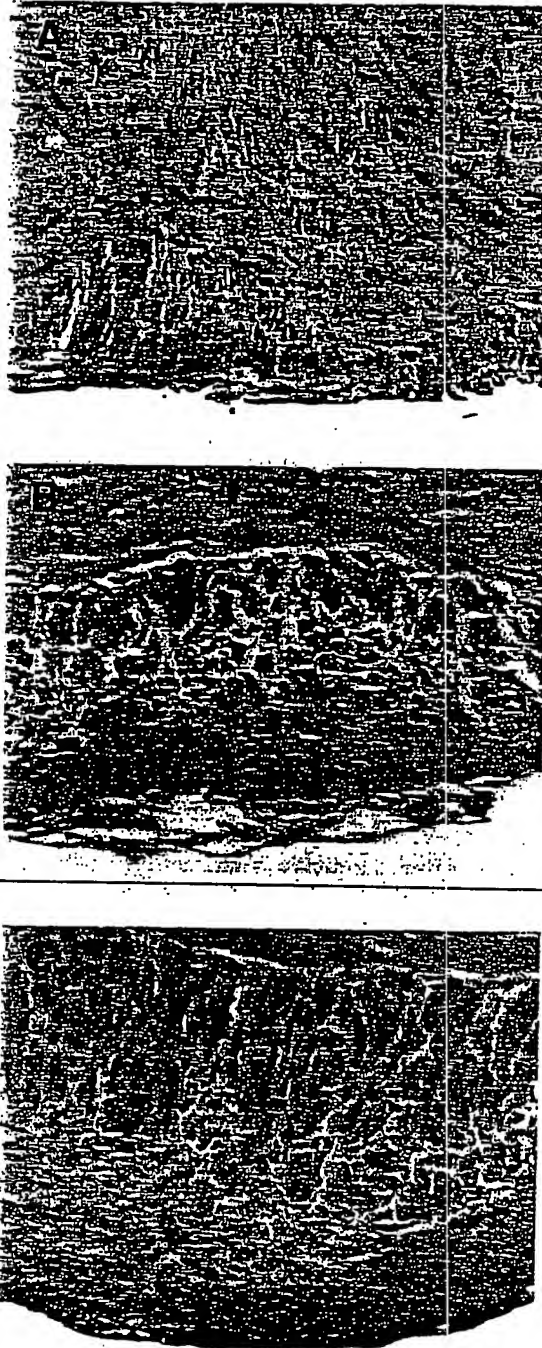


Fig 2. Indirect, steam bubble-mediated thermal damage after EVLT, several millimeters away from areas of direct laser impact. A, Control: normal varicose vein after stripping without earlier EVLT, with intact endothelium and distinct cellular contours. The nuclei are round to oval. B, EVLT resulted in a lift-off of endothelial cells, a denudation of the intima, loss of cellular contours, and fibrin deposition. Additionally, some areas show marked vacuolization of cells or even spongiosis. C, Swelling and waxy homogenization of collagen. Focal coagulation necrosis within the intima.

steam bubble formation is expected to occur within the vein lumen during EVLT, we propose that this phenomenon accounts for the thermal injury to an extended surface of the inner vein wall.

In a recent paper, Sadick et al<sup>10</sup> reported histopathological alterations of reticular veins and venulectasias after transcutaneous neodymium/yttrium-aluminum-garnet laser treatment that compare well with our findings. This opens the question of whether also in transcutaneous laser treatment of smaller veins the crucial damage of the vein may involve a similar steam bubble-mediated, hence indirect, thermal injury, rather than the immediate highly focused damage by the laser beam itself.

Steam bubble formation is a local, instantaneously reversible phenomenon that, after collapse of the bubble, poses no risk, such as gas embolism, to the patient. However, the extensive heat damage of the endothelium and the intima does induce the desired effect: full-length thrombotic occlusion of the vein. The complete thrombotic occlusion, however, is not detectable immediately after EVLT, but can be recognized at day 1 by means of a simple duplex scanning examination, which shows an incompressible, hypoechogenic cord in the lumen of the saphenous vein. This thrombotic occlusion is also reflected in all patients with an increase of D-dimer levels in peripheral blood by a median factor of 1.43. Because in our study and another study<sup>9</sup> no EVLT-induced deep vein thrombosis occurred, it seems very unlikely that the EVLT-induced thrombotic process of the GSV has a concomitant risk for deep vein thrombosis, as is known for superficial thrombophlebitis.<sup>11</sup> However, it remains unclear whether such an hypothetical risk of deep vein thrombosis does indeed exist or whether it is only so much lower compared with superficial thrombophlebitis<sup>12</sup> that it can only be detected in a larger series of patients.

Other commonly observed adverse effects with EVLT are induration along the GSV and mild-to-moderate ecchymoses. These ecchymoses, present for approximately 2 weeks, could be a cosmetic problem for patients who are expecting a minimally invasive, barely invisible treatment of their GSV incompetence. In this respect, EVLT would compare unfavorably with endoluminal radio-frequency closure. However, when weighed against the potential nerve damage after endoluminal radio-frequency treatment with subsequent skin paresthesia in as many as 16% of patients,<sup>7</sup> such an entirely reversible adverse effect seems quite acceptable.

Less frequent adverse effects, like thrombophlebitis of untreated tributaries or appearance of hyperpigmentation along the GSV, need to be followed and documented as the number of patients and EVLT procedures increase. At least the risk of thrombophlebitis could be avoided completely if varicose tributaries, unlike in the present series, are treated in the same session (eg, with mini-phlebectomy).<sup>1,2</sup>

Finally, it remains to be established whether EVLT induces effective long-term occlusion of the treated veins. Recurrent reflux, either originating from the SFJ or reoc-

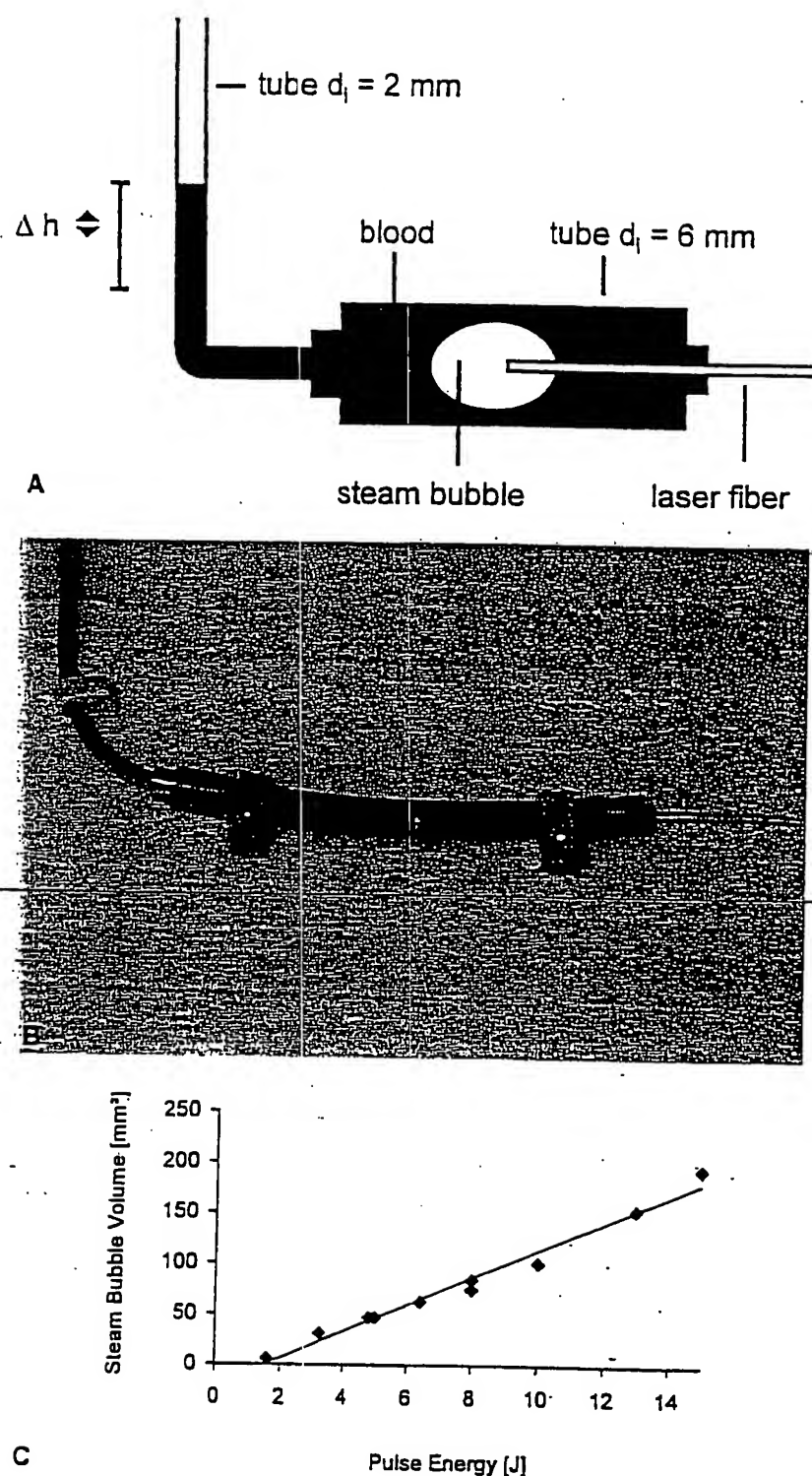


Fig 3. A, Schematic drawing of the in-vitro set-up for examining the laser-generated steam bubble formation. The laser fiber was inserted into a silicone tube of 6-mm-diameter filled with heparinized blood. During delivery of laser energy, heating and boiling of the blood finally lead to the formation of a steam bubble, pushing the corresponding blood volume out of the tube. Thus, the movement of the blood level in the smaller 2-mm-diameter tube allowed the calculation of the volume of the steam bubble in reverse. B, Visible steam bubble formation during delivery of a laser pulse of 15 J. C, Dependency of the steam bubble volume for various amounts of energy delivered by the laser beam.

curing within recanalized parts of the GSV, has to be followed closely. Only long-term follow-up in prospective trials will be able to answer this question.

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Submitted Aug 15, 2001; accepted Oct 12, 2001.

## **APPENDIX 3**



IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No. : 10/699,212 Confirmation No.: 2780  
Applicant : David R. Hennings et al.  
Filing Date : October 30, 2003  
Title : Endovenous Closure of Varicose Veins with Mid Infrared Laser  
Group Art Unit : 3739  
Examiner : David M. Shay  
Docket No. : 15487.4002  
Customer No. : 34313

Mail Stop AMENDMENT  
Commissioner for Patents  
PO Box 1450  
Alexandria, VA 22313-1450

**DECLARATION OF DAVID R. HENNINGS**

I, David R. Hennings, do declare and say as follows:

1. I am one of the inventors named in the above-identified application.
2. Attached hereto as Exhibits A-E are, respectively, true copies of product literature published by Dornier MedTech, biolitec, AngioDynamics, Vascular Solutions and Diomed, respectively.

Further, Declarant sayeth not:

---

CERTIFICATE OF MAILING (37 CFR §1.8)

I hereby certify, pursuant to 37 CFR §1.8, that I have reasonable basis to expect that that this paper or fee (along with any referred to as being attached or enclosed) would be mailed or transmitted on or before the date indicated with the United States Postal Service with sufficient postage as first class mail on the date shown below in an envelope addressed to Mail Stop Amendment, Commissioner for Patents, PO Box 1450, Alexandria, VA 22313-1450.

Dated: July 5, 2005

Lynne Fulmer  
Lynne Fulmer

DOCS001:164538.1

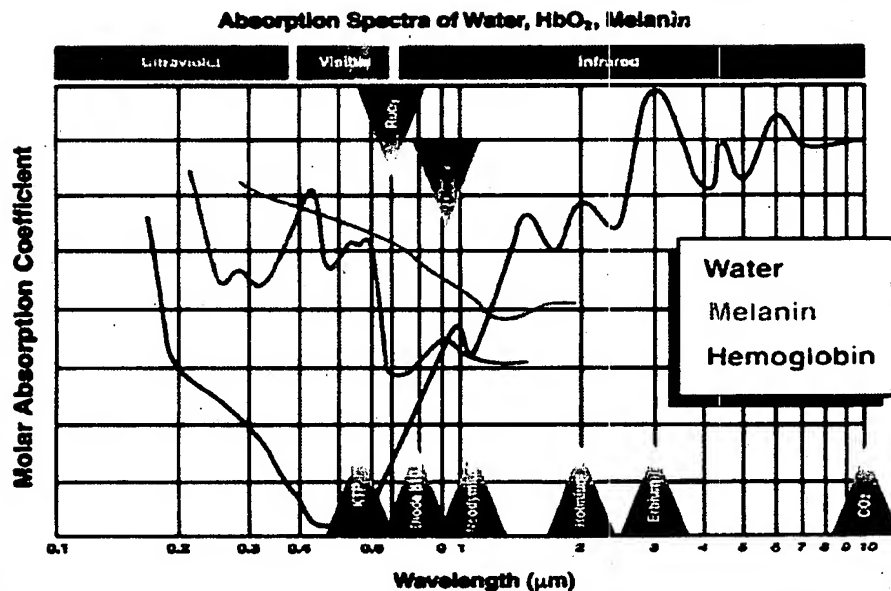


Applicant : David R. Hennings et al.  
Appl. No. : 10/699,212  
Examiner : David M. Shay  
Docket No. : 15487.4002 (Formerly NSL-501)

I declare under penalty of perjury that the foregoing is true and correct. Executed this 30  
day of June, 2005 at Roseville, California.

  
\_\_\_\_\_  
David R. Hennings

# The Dornier **D940 Laser** Wavelength



*The highly unique light of a 940 nm wavelength ensures precise targeting of spider veins because of its ...*

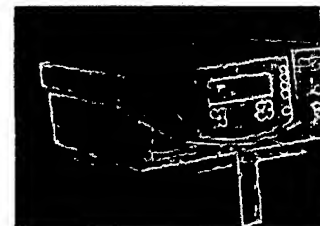
- Deep penetration
- Optimal absorption characteristics for hemoglobin (3x more than an 810 or 1064 nm laser)
- Optimal absorption characteristics for water (10x more than an 810 nm laser, and 3x more than a 1064 nm laser)
- Minimal melanin absorption when compared to other lasers (3x less than an 810 nm laser, which enables treatment of darker skin-types)

*These absorption characteristics result in a safer and more effective treatment for both spider and varicose veins.*

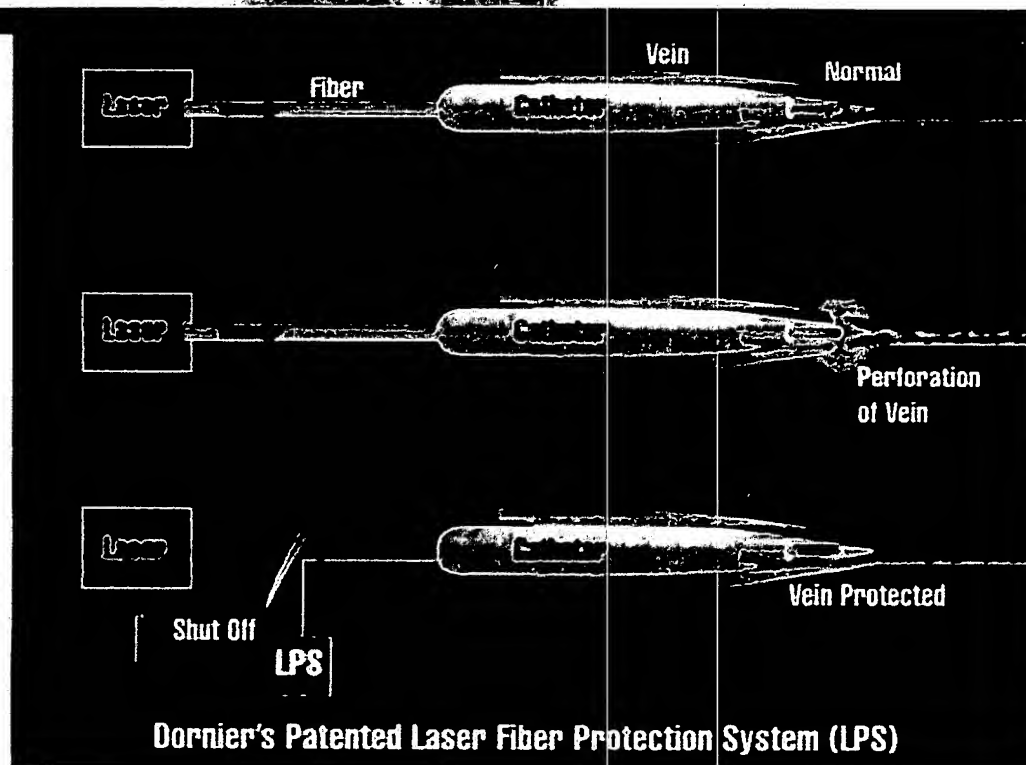


Built-in Safety While Performing Endovenous Treatments ...

## The LPS Fiber Protection System



The Dornier D940



### Normal Operation

A normal fiber tip achieving optimal results on vein tissue layers.

### No LPS Feedback

Fiber tip starts to char, absorbing laser light and producing unwanted damaging heat.

### LPS Feedback

Tip has charred, triggering feedback and the LPS shut off for protection.

### Technical Data

**Wavelength**  
940 nm

**Laser Power at Tissue**  
Pulse mode: 120 w  
Continuous wave: 1-60 w

**Aiming Beam**  
Red aiming beam standard  
(Green beam option for better visibility)  
Power 0-150mW adjustable

**Laser Transmission System**  
Lightguides: core diameter 600µm  
Lightguide connector: SMA modified

**Application Modes**  
Pulse: removal of unwanted hair, vascular treatment  
Standard: coagulation/ablation  
Fibertom: contact cutting  
LIF: interstitial coagulation

### Pulse Mode

Pulse energy: up to 10J  
Pulse duration: 10-100 ms  
Pulse interval: 200 ms-2 s  
or Pulse repetition: up to 5 Hz

### Record

Simultaneous display of applied energy, irradiation time and number of pulses

### Power Supply

100-240 V, 50/60 Hz, 1.3 KVA

**Dimensions (HxWxD)** 8"x19"x20"

### Weight

35 pounds

### Standards/Classifications

IEC 601, IEC 825 European medical device directive Device protection class 1, BF  
Laser class IV

*The Dornier D940 laser system is a must for any serious laser center or physician practice.*

### About Dornier MedTech ...

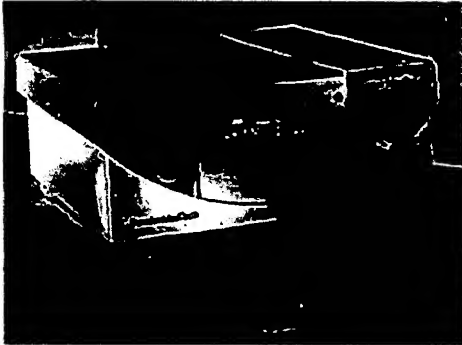
Specializing in lithotripters, orthopedic shock wave devices, urologics and medical lasers, Dornier MedTech has operating units and service partners throughout the world - and continues to maintain its commitment to the medical device industry by providing innovative therapeutic, diagnostic and service solutions for numerous medical fields.

**“The Dornier 940 nm laser is the most effective to date for the treatment of spider veins. This same laser will also replace stripping in 85% of patients who have saphenous vein insufficiency.”**

Ron Bush, MD, FACS  
Midwest Vein Treatment Clinic



# Dornier MedTech Americas



## Dornier D940 Diode Laser System

Dornier specifically chose the 940 nm wavelength to design the D940 diode laser system for the treatment of superficial veins, as well as saphenous vein insufficiency.

The Dornier D940 is the first and only laser to emit light at 940 nm and is engineered with the newest PowerBar® technology to provide high peak powers from a small package.

Weighing only 55 pounds, the Dornier D940 is lightweight and easily transportable, with a retractable handle and built-in wheels. Plugs into any 110-volt outlet and is backed by Dornier's nation-wide service organization.

**The highly unique light of a 940 nm wavelength ensures precise targeting of vessels because of its:**

- Deep penetration
- Optimal absorption characteristics for hemoglobin (3x more than an 810 or 1064 nm laser)
- Optimal absorption characteristics for water (10x more than an 810 nm laser, and 3x more than a 1064 nm laser)
- Minimal melanin absorption when compared to other lasers (3x less than an 810 nm laser, which enables treatment of darker skin-types)

These absorption characteristics result in a safer and more effective treatment for both spider and varicose veins.

Close Window



**Dornier MedTech**

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therapy



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## 980nm Diode Laser Series



biolitec's 980nm Diode Laser Series, including the Ceralas D and SmilePro 980 Lasers, are ideal for soft-tissue applications in medical, dental, and veterinary environments.

With unsurpassed, optimal absorption in water and hemoglobin, the 980 nm laser series allow controlled tissue ablation and provide a bloodless field for most surgical procedures. Unlike other medical lasers, biolitec's 980nm lasers cut and coagulate optically — with negligible collateral tissue damage, charring,

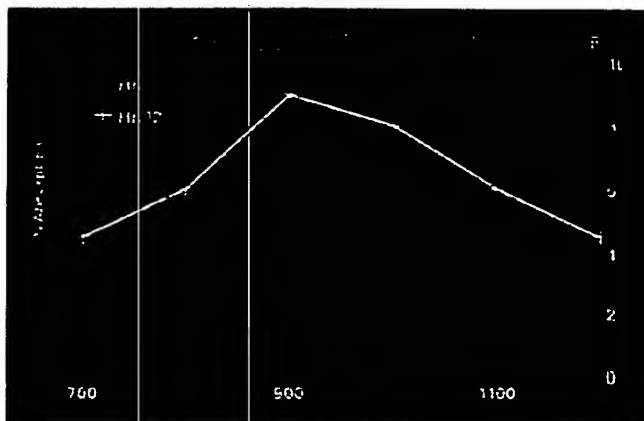
and recession. Many procedures using the 980nm lasers are pain-free, minimizing or even eliminating the need for anesthesia. These state-of-the-art 980nm lasers are compact and portable at 15 pounds and require no special cooling or maintenance.

More information about the SmilePro 980 for Dentistry.

More information about the Ceralas D for medical applications.

### ELVeS™ – Endo Laser Vein System

ELVeS is a revolutionary new minimally-invasive laser treatment for superficial reflux of the greater saphenous vein - which may lead to varicose veins. Progressing the capabilities of vein treatments, ELVeS takes about 45 minutes and only local anesthesia is used - allowing patients to walk home after treatment! With virtually instant relief from venous reflux, patients can return to their normal lifestyle and activities immediately following treatment.



## Other Laser Wavelengths

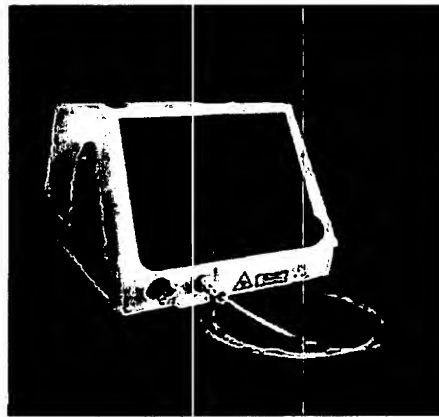
Other lasers' wavelengths are either absorbed too much or too little in water and / or hemoglobin and are consequently limited in several ways.

The 810 nm lasers' energy is eight times less absorbed in water than the 980 nm wavelength. Therefore, 810 nm lasers' fibers require 'conditioning' because their wavelengths can not properly ablate tissue. The conditioned tip of these lasers' fibers needs to heat up in order to work. In addition, the light energy from these lasers is absorbed in their fibers' tips - not in water, hemoglobin, or tissue. The laser light never reaches the patient - only the heat via a 'hot tip.'

Conductive heat is the only means of cutting and coagulating with lasers that require conditioned tips - which can damage collateral tissue and cause swelling, excessive necrosis, and patient discomfort.

## The 980 nm Wavelength

A major benefit of the Ceralas D 980 nm Laser's unique wavelength is the ability to operate optically - not via a 'hot tip.' Because hemoglobin and water absorb



the 980 nm wavelength at an optimal rate, the fiber tips of the Ceralas D laser do not require conditioning.

Because the Ceralas D exhibits superior control and minimizes collateral tissue damage, it is one of the most valuable and versatile lasers available today. "Although the 810 nm diode laser has been used for endovenous treatment, I feel it is not the best wavelength, as it does not absorb well in water," says John Mauriello, MD, a phlebologist in private group practice with offices in Charlotte and Durham, North Carolina.

"The 940 nm diode laser is better than the 810 nm because it is on the up-slope of the water absorption curve. But my research convinces me that 980 nm is the perfect wavelength because it is right on the peak of the water absorption curve."

[ELVeS FAQs](#)

[The ELVeS Procedure](#)

[Advantages of biolitec's Endo Laser Vein System for Doctors](#)

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FREE SmilePro 980 Dental Marketing Kit



SPECIALTIES

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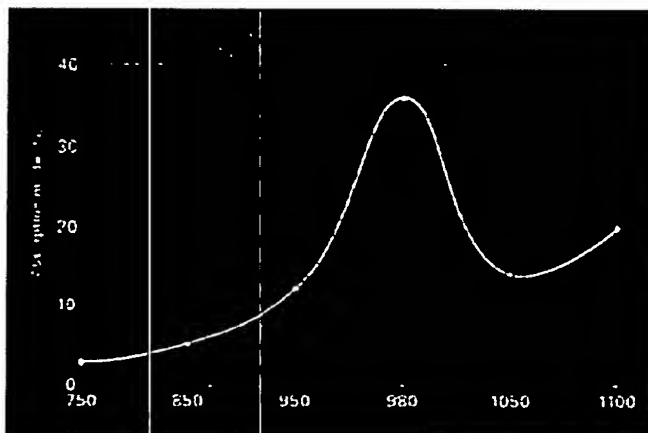
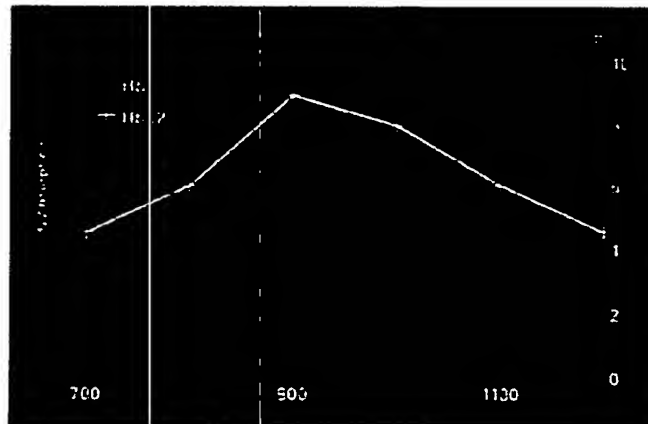
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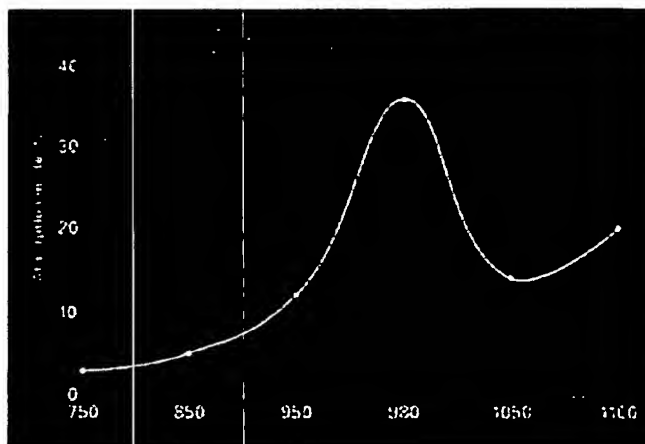
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## The Importance of a Laser's Wavelength: Advantages of 980 nm

A laser's wavelength determines many of its properties and capabilities. As a result of **biolitec's** extensive research in photobiology and laser physics, we have developed a series of 980 nm lasers that exhibit unparalleled lasing effects.

Since soft tissue contains a high percentage of water and hemoglobin, a laser's light energy must be well absorbed in both to cut and coagulate optimally. Considering the absorption characteristics of water and hemoglobin together, 980 nm is the ideal wavelength for soft tissue applications - including the ELVes Treatment for superficial reflux of the GSV, which often leads to varicose veins.





### SmilePro 980 Technical Specifications

Laser Type	Integrated GaAlAs semiconductor laser arrays
Wavelength	980 nm
Output power	15 Watts
Power Range	1 - 15 W
Output power increments	1 Watt
Operating modes	Continuous or Pulsed
Pulse duration in On or Off modes	0.01 to 99.9 seconds
Aiming beam	Visible semiconductor (635 nm, red) 4 mW
Cooling	Air cooled
Weight	15 lbs
Dimensions	7" x 9" x 14" (h x w x d)
Power requirement	110 / 220 V

### Ceralas D Technical Specifications


Laser Type	Integrated GaAlAs semiconductor laser arrays
Wavelength	980 nm
Output power	15 W, 25 W, 50 W
Power Range	1 - 15 W, 1 - 25 W, 1 - 50 W
Output power increments	1 Watt
Operating modes	Continuous or Pulsed
Pulse duration in On or Off modes	0.01 to 99.9 seconds
Aiming beam	Visible semiconductor (635 nm, red) 4 mW
Cooling	Air cooled
Weight	14 lbs (15 W, 25 W); 19 lbs (50 W)
Dimensions	7" x 9" x 14" (15 W, 25 W); 7" x 15" x 16" (50 W)
Power requirement	110 / 220 V

For more information, contact your local sales representative or send an email to us at [info@biolitec.com](mailto:info@biolitec.com).

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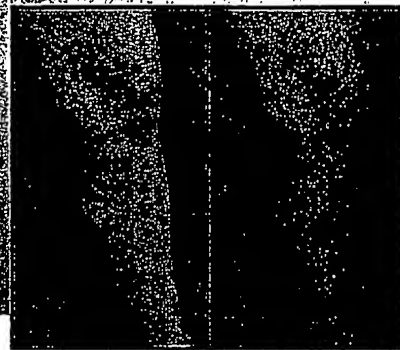
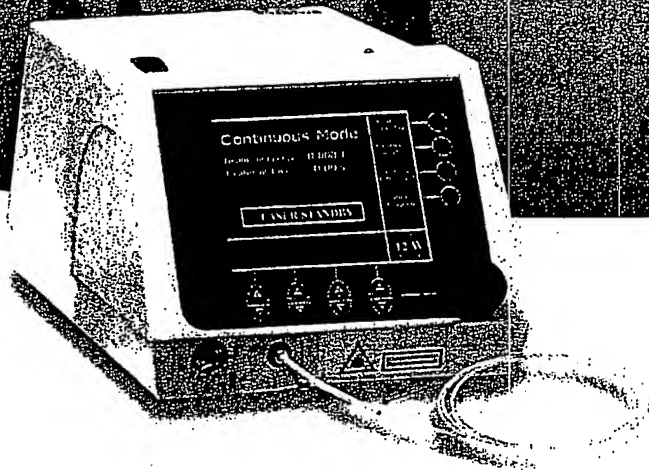




# VenaCure™

Laser Vein Treatment

Get your vein practice  
up and running!



BEFORE

AFTER

## ANGIODYNAMICS®

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Use the power and precision  
of VenaCure laser technology  
to build your business and  
your future!

Only AngioDynamics offers you a choice  
of laser frequencies. Whichever you select,  
you'll have a dependable, high-quality  
instrument.

- Up to 15 watts of optical power from  
a compact, air-cooled unit

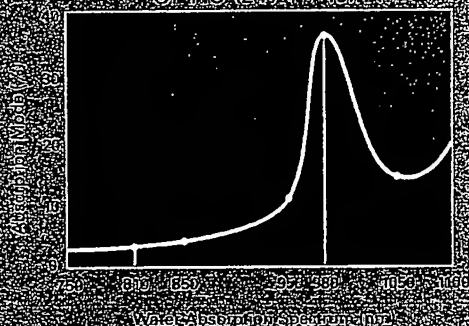
- High-efficiency power supply, micropro-  
cessor, and adjustable laser output with  
automatic power stabilization

- Switch panel and display panel featuring  
a clear, intuitive design

- Diode lasers protected with a rugged,  
replaceable environmental protective  
enclosure

- High-capacity fans to cool the heat  
in water cooling and assure low mainte-  
nance and reliable laser operation

OPTICAL PATH 10mm



Choose from the Precision 810, 980 optical  
hemoglobin absorption or the Precision 980  
for peak water absorption.

## VenaCure Precision 980™ Laser Specifications

Laser Type	Integrated GaAlAs semiconductor laser arrays
Wavelength	980 nm
Output Power	15 W
Power Range	1-15 W
Increments	1 or 5 W
Operating Modes	Continuous, Pulsed
Pulse Duration ON/OFF	0.01 to 99.9 sec
Aiming Beam	635 nm; 4 mW
Cooling	Air cooled
Weight	15 lbs (6.8 kg)
Dimensions	14" x 9" x 7"
Power Requirements	110/220 V
Fiber Connector	Standard SMA 905

## Ordering Information

NEW VenaCure™ Procedure Kit 45cm	11402001
NEW VenaCure™ Procedure Kit 65cm	11402002
Precision 980™ Laser	11400201
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# *VarizLase*<sup>®</sup> VALUE

*Vascular Solutions' commitment  
to helping you build a successful  
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*Professional Products*

*Professional Service*

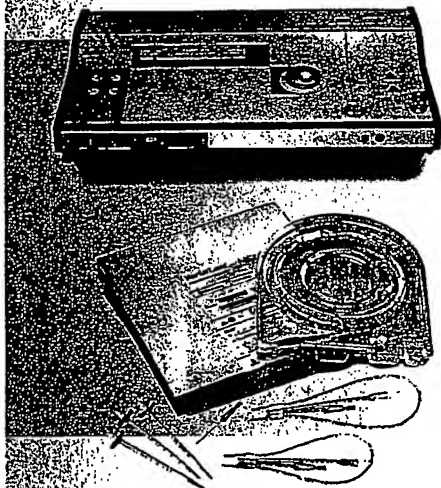
*Professional Support*



**vascular**  
SOLUTIONS



*Vari-Lase Value... all the professional products, services and support you need to build a successful vein practice*



### *A complete line of professional Vari-Lase products for endovenous laser therapy*

- Vari-Lase procedure kits
- Vari-Lase 810 Laser Console
- Fibers, catheters and other product accessories

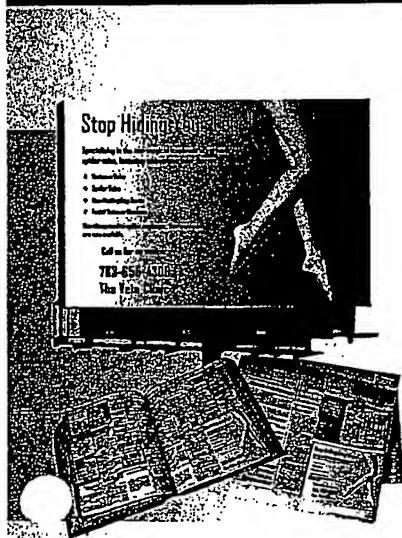
Vari-Lase products are designed with the vein practice in mind. The Vari-Lase kit is not just a box of components but a professionally designed procedure kit for endovenous laser treatment of superficial venous reflux. This kit comes in a variety of configurations. In addition, Vascular Solutions offers a full line of micro-introducer kits, tear-away kits and guidewires -- everything you need to keep your practice running smoothly.



### *Physician Training - Clinical & Business*

Vascular Solutions is dedicated to providing the finest vein care training available for physicians and their staff.

With training centers located throughout the United States and Germany, Vascular Solutions offers its partners the most comprehensive education available on the clinical procedures and practice management of total vein care.



### *Marketing & Advertising Support*

Vascular Solutions provides real assistance in getting the word out about your vein practice. Marketing assistance includes:

- Selection of customized display ads designed for use in newspapers, yellow pages and various graphic designs
- Set of customizable press releases for use in a wide range of publications
- Consultation with a designer when preparing advertisements
- Powerpoint presentation on vein disease for use in public forums, such as health fairs


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## Vari-Lase Endovenous Procedure Kit.

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Vari-Lase endovenous procedure »  
kit

**Vari-Lase- the professional endovenous laser procedure kit.**

**Better. Easier. Professional.**

Vari-Lase is not just a box of components but a professionally designed procedure kit for endovenous laser treatment of superficial venous reflux.

The Vari-Lase procedure kit is indicated for the treatment of varicose veins associated with superficial reflux of the great saphenous vein.

The Vari-Lase procedure kit can be used in conjunction with any solid state diode laser console accepting a standard SMA-905 connector and operating at a wavelength of 810nm, 940nm, or 980nm and a maximum power of 15W.

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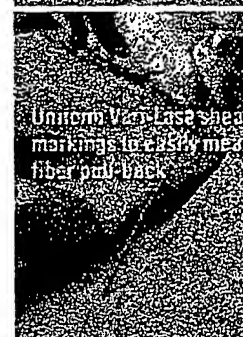
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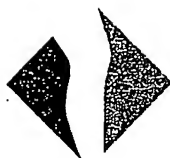
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**EVLIT** non-surgical  
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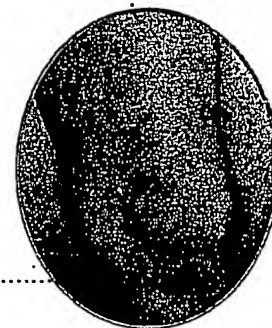
**THE GREATEST EXPERIENCE IN  
ELIMINATING VARICOSE VEINS**

Advanced Technology

Expert Training

Practice Growth

Before EVLT®



After EVLT®



DIOMED

# VEINS

## Equipment

EVL<sup>®</sup> is performed with a 15 watt, 810nm DIOMED Diode Laser that is:

**Compact and portable** – fits in the treatment room and can be transported easily

**Quick to set up** – runs from a standard electrical wall socket; ready for use in seconds

**Easily maintained** – designed as a solid state system and has no moving parts

**Easy-to-use** – gives immediate access to treatment options and operating modes

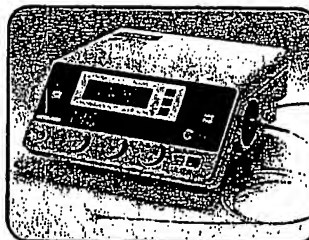
**Versatile** – can be used in transdermal applications to treat spider veins and smaller vascular lesions (D30 Plus)

Disposable accessories are provided in a convenient "single use" EVLT<sup>®</sup> Procedure Kit that includes:

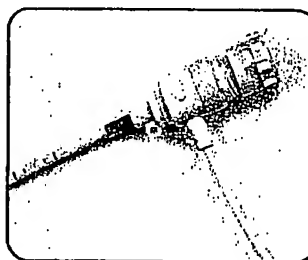
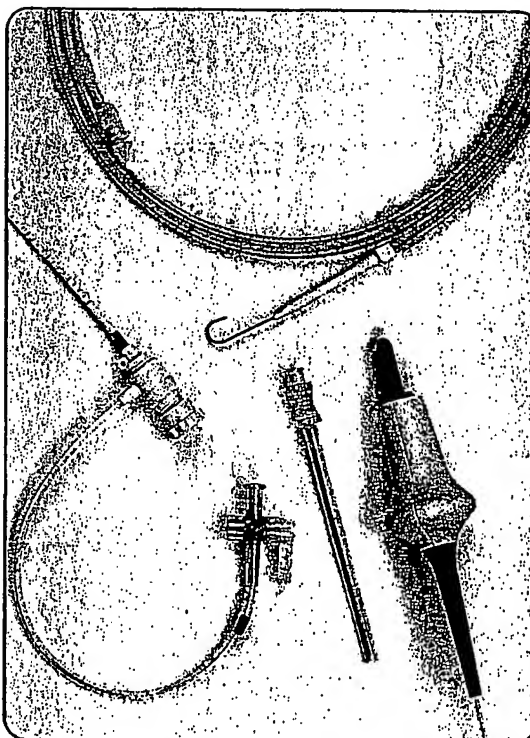
- EVLT<sup>®</sup> laser fiber with SiteMarks<sup>™</sup>
- Percutaneous entry needle or micro-access kit
- Guide wire
- Custom introducer sheath with graduated markings (standard and long version)

### PRECISELY THE RIGHT WAVELENGTH

The specific 810nm wavelength used in EVLT<sup>®</sup> is set to target vein treatment. Its safety and efficacy have been tested and proven in multiple clinical studies.



A red aiming beam identifies the exact position of the fiber within the vein.



Specialists in Interventional Radiology, Phlebology, and Vascular Surgery helped design the EVLT<sup>®</sup> procedure kit with their patients and practices in mind. It is easy to use, economical, and convenient.

**Safety Ensured:** The first SiteMark<sup>™</sup> tells the user that the fiber tip is at the end of the sheath. Drawing the sheath back to the second SiteMark<sup>™</sup> brings the fiber out three centimeters and positions it properly at the saphenofemoral junction.